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NOTES

ON

NAVAL PROGRESS.

JULY, 1900.

DEPARTMENT OF THE NAVY
BUREAU OF NAVIGATION

OFFICE OF NAVAL INTELLIGENCE.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1900.

War 38.
~~VI 2662~~
(c IV, 7

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OFFICE OF NAVAL INTELLIGENCE.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1900.

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INTRODUCTION.

Following custom, these Notes on Naval Progress are brought up to July 1, 1900. As the publication of the last annual was delayed—that number including notes to November, 1899—the period covered by the present number is shorter than usual.

It was hoped that an account of the Japanese naval manœuvres might be given in this number, but as the attendance of foreign officers and press representatives was not permitted, informaion of sufficient value for publication is not available.

Especial attention is directed to the article on "The electrical equipment of ships of war," by Mr. C. E. Grove, a liberal quotation from which appears in Chapter V, and also to the lecture on "The employment of spark telegraphy in the Navy," by Mr. A. Slaby, in the same chapter. It is believed that these articles are of special interest to the service.

C. D. Sigsbee,
Captain, U. S. N., Chief Intelligence Officer.

Navy Department, *July 1, 1900.*

Approved.
A. S. Crowninshield,
Chief of the Bureau of Navigation.

I.

INCREASE IN NAVAL STRENGTH AS SHOWN BY NAVAL BUDGETS.

By Lieutenant William L. Howard, United States Navy,
Staff Intelligence Officer.

Naval expansion is the order of the day. A study of the budgets of the various naval powers, the building programs as outlined therein, and the constantly increasing amounts devoted to new construction, all serve to indicate the serious attention given to the subject of naval increase.

England, as usual, leads with the largest sum for the support and increase of her navy. But large as is this total, it is generally felt that the Admiralty program is inadequate, and the press of that country is actively urging a further increase.

The following translation of an article which appeared in *La Petite République* of October 9, 1898, sums up the situation very clearly:

> The Spanish-American war and the rapid and brilliant success of the United States, the growing importance of colonial enterprises and commercial operations, and the formidable questions connected with the early opening of China, all show that the military contests of the future will not be decided on the continent of Europe, but upon the sea, and probably in the Far East, on the Pacific Ocean, since Europe has decided that not only Africa and Australia, but also all Asia, must be considered as colonies belonging to her.
>
> Wars for political supremacy will henceforth be naval wars, especially if in consequence of the community of interests between England and the United States, of which we have often spoken, the next war is brought about by the great economic interests which have recently accentuated the antagonism which has long existed between England and Russia.
>
> In view of these facts it is easy to understand that the importance of standing armies is diminishing more and more. They are instruments of war which can be transported and employed only to a limited extent at the scene of the contests which the future has in store for us.
>
> After the success of Germany in the campaigns of 1866 and 1870–71, the European powers hastened to increase their standing armies; England even appeared anxious to enter the new road by renouncing the system of voluntary enlistment and adopting obligatory conscription.

Now, however, things are about to change. It is the naval forces that are being increased. Russia, Germany, France, Italy, and even Japan are going to immense expense to that end. It is only necessary to recall the recent credits voted by the great maritime powers of Europe; and the result of the Spanish-American war, achieved almost solely by the navy, can but further the development of the fleet.

Until recently continental Europe had been the scene of the great wars, but the results obtained were not proportionate to the efforts made. Moreover, under the influence of socialistic agitation, frontier questions have lost much of their importance. The *revanche* of France, the *irrédentisme* of Italy, even the reestablishment of Poland, no longer occupy public opinion to the same extent; its attention is now called to other questions of gigantic proportions which present themselves in Africa, China, and the Far East. Therefore the necessity of large standing armies for foreign wars has ceased.

The maintenance of naval forces imposes much greater expense upon a country than that of standing armies; the increase of the budgets of those countries which are most interested do not leave any doubt as to this, and we are only just beginning; for it is not only a question of increasing the number of ships, arming them and instructing their crews, but also of establishing a large number of naval stations which, while necessary, is much more difficult. The lack of coaling stations was one of the causes of Spain's defeat.

This is why the maintenance of a navy requires such enormous expense and why it is not possible to obtain appreciable results if a country does not have at its disposal a formidable budget and if it can not count upon the reinforcement of the navy by a large merchant marine and upon the development of metallurgic industries.

Under these conditions agricultural countries do not appear to be called upon to become maritime powers of the first order, for there we find neither the necessary means for creating and mobilizing naval forces on a large scale, nor the elements for the reenforcement and repair of the fleet if the war should continue for any length of time.

Thus the removal of the axis of warfare from the army to the navy is not an accidental phenomenon, but the result of the political and social changes which are now in progress and which will bring about a new classification among the powers, one which takes cognizance not only of their financial resources, but also of the industrial progress which they achieve.

From this point of view, England, the United States, and later on Japan, perhaps, appear called upon to play the most important rôles in the naval wars of the future.

ENGLAND.

Parliament and the nation have long accepted the principle that her naval strength must be equal in numbers and superior in power to that of the two strongest navies of the world, and the British estimates, which include the program of new construction, are based on this principle. Accordingly, no building scheme covering a period of years is projected, but instead a yearly program of new construction, in accordance with a carefully devised plan for the construction of a homogeneous fleet and based on the principle stated, enables England to maintain this superiority. Her program is therefore outlined by the programs of the other powers.

The navy estimates for 1900–1901 amount to a gross total of £28,553,222. From this amount should be deducted the sum of

£1,030,622, being appropriations in aid, leaving the net total budget £27,522,600, which is an increase of £928,100 over that of last year.

The following table shows the sums authorized and the yearly increase since 1894:

Year.	Gross appropriation.	Increase.
1894–95	£18,371,713	£3,104,039
1895–96	19,613,821	1,242,108
1896–97	22,774,318	3,160,497
1897–98	23,280,473	506,155
1898–99	24,733,822	1,453,349
1899–00	27,578,039	2,844,217
1900–01	28,553,222	975,183

SHIPBUILDING PROGRAM.

Under the program of new construction it is proposed to lay down this year—

Battleships	2	Sloops	2
First-class armored cruisers	6	Gunboats	2
Second-class cruiser	1	Torpedo boats	2

This will give the following list of ships under construction in 1900:

Battleships	17	Sloops	8
Armored cruisers	20	Torpedo boats	4
First-class protected cruiser	1	Destroyers	21
Second-class protected cruisers	2	Royal yacht	1
Third-class cruiser	1		

There have never been so many vessels under construction as at the present time. In 1899 England added 19 vessels to her fleet, aggregating 122,322 tons, and in 1898, 30 ships, with a total tonnage of 140,988.

The following table gives ten years' production of naval shipbuilding:

Year.	Number built.	Tonnage.	Year.	Number built.	Tonnage.
1890	21	64,995	1895	36	136,762
1891	18	107,250	1896	35	104,485
1892	22	141,200	1897	26	65,996
1893	14	34,310	1898	30	140,988
1894	27	31,525	1899	19	122,322

An increase of 4,240 in the naval establishment was voted, making the total strength of the navy 114,880 officers and men. The addition proposed is distributed as follows:

Officers	320
Petty officers and seamen	3,050
Engine-room staff	150
Miscellaneous	200
Marines	300
Apprentices (artisan ratings)	320
Total	4,240

The following table best illustrates the steady increase in personnel:

Year.	Total naval force.	Year.	Total naval force.
1893	74,700	1897	100,050
1894	83,400	1898	106,390
1895	88,850	1899	110,640
1896	93,750	1900	114,880

In addition to this total, a naval reserve of 26,750 seamen and firemen is authorized by law, of which number 25,712 are actually enlisted.

FRANCE.

The shipbuilding program of 1896, which covered a period extending to 1907, provided for the construction of 220 vessels, as follows:

Battleships of 12,000 tons	6	Gunboats	4
Armored cruisers, 7,000 to 9,000 tons.	9	Aviso torpedo boats	10
Protected cruisers of 4,000 tons	8	Destroyers	25
Protected cruisers of 2,500 tons	3	Squadron torpedo boats	38
Avisos	3	Seagoing torpedo boats	112

These vessels were to cost 621,670,000 francs. The amount to be expended up to January 1, 1900, for 79 vessels was estimated at 313,440,000 francs, but according to more recent estimates this will amount to 337,700,000 francs. There remains, therefore, 141 vessels to construct, but beyond finishing the ships already laid down, the program of 1896 is practically abandoned.

The minister of marine now proposes a substantial building program which will supply the number of vessels of various kinds that are necessary to make the French navy a homogeneous force. This program comprises the laying down of the following vessels, beginning this year:

Battleships	6	Torpedo boats	112
Armored cruisers	5	Submarine or submergible boats	26
Destroyers	28		

This will give the French fleet, after its execution—

Battleships—4 squadrons of 6 battleships, with a spare battleship for each squadron	28
Armored cruisers—8 divisions of 3 cruisers each	24
Destroyers	52
Torpedo boats	263
Submarine boats	38

The vessels of the new program are estimated to cost 476,832,000 francs. To this sum is to be added 235 million francs, the latter being the amount necessary to complete the vessels laid down up to January 1, 1900, and which will all be finished by 1903. The two programs will be entirely completed in 1907. The total cost of new construction amounts to 712,208,000 francs. In addition to this amount it is proposed to expend about 140 million francs on the improvement of the various arsenals and naval stations.

The annual cost of the two programs is apportioned as follows:

Year.	New program.	Old program.	Total.
	Francs.	*Francs.*	*Francs.*
1900	3,836,000	100,026,000	103,862,000
1901	28,490,000	75,383,000	103,873,000
1902	54,450,000	39,003,000	93,453,000
1903	75,162,000	16,389,000	91,551,000
1904	93,524,000	3,945,000	97,469,000
1905	99,484,000	210,000	99,694,000
1906	81,823,000	210,000	82,033,000
1907	40,063,000	210,000	40,273,000
Total	476,832,000	235,376,000	712,208,000

GERMANY.

Increase of the navy was a leading topic in 1897, and with a view of educating the public to this necessity the Government published a series of statistics on the growth of the maritime interests of the German Empire. These publications showed the increase in population, the enormous increase in foreign trade, and a special publication was issued to show the backward state of the German fleet. The general conclusions were that the Empire was behind all other great powers, except Austria-Hungary and the United States, as regards a navy, and that the expenditure for national defense, inclusive of the public debt, was extremely low when compared with that of foreign nations.

Then followed a naval bill carrying a definite shipbuilding program extending over a period of seven years, which was later cut down to six years and known as the Sexennate law. This law was passed April 10, 1898, and provided for the following strength of the German fleet, apart from destroyers, torpedo boats, etc.: 17 battleships, 8 coast-defense vessels, 9 large cruisers, 26 small cruisers, as a fighting fleet ready for sea, and a further reserve of 2 battleships, 3 large cruisers, 4 small cruisers.

The above was considered a minimum of the requirements for the Government to carry out its obligations. On April 1, 1898, Germany possessed, either built or building, 12 battleships, 8 coast-defense vessels, 10 large and 23 small cruisers, thus leaving to be built 7 battleships, 2 large and 5 small cruisers. The bill also provided that successive estimates should contain provisions for the replacing of old by new ships, and laid down the principle that the life of a battleship and coast defense ship should be considered as twenty-five years, that of a large cruiser as twenty years, and a small cruiser fifteen years; after which time they should be considered old within the meaning of the law and replaced by new construction.

The strength of the fleet as contemplated by the Sexennate law has already been attained, and increase of the navy is again the most important topic of the day. A most comprehensive bill for the increase of the fleet is now before the Reichstag, and while there is considerable opposition, it will probably be passed with perhaps slight modifications.

The portion of the bill relating to the increase in number of ships reads as follows:

I. NUMBER OF SHIPS.

SECTION 1.

1. The number of ships provided for under the law of April 10, 1898, concerning the German fleet shall be increased by—

(*a*) Available—
  1 flagship.
  2 squadrons of 8 battleships each.
  2 large cruisers } as scouts for the home battle fleet.
  8 small cruisers }
  5 large cruisers } for service on foreign stations.
  5 small cruisers }
(*b*) As reserve matériel—
  2 battleships.
  1 large cruiser } for service on foreign stations.
  2 small cruisers }

and shall be decreased by two divisions of 4 coast-defense battleships each.

2. In this increase the 8 coast-defense battleships shall be counted as line-of-battle ships until replaced.

This bill provides for such a large increase and extends over such a long interval that it is worthy of careful study. In the argument for the necessity of this proposed increase is sounded the keynote of the requirement for a strong navy. "*Germany requires peace on the sea.*" The policy of the Emperor is for a navy so strong that no power will dispute with her there. The arguments presented for so comprehensive a program may be summed up as—

1. No such large program is possible unless it is indicated by law that it is the fixed purpose of the Government to carry it out.

2. It would be impossible to get the necessary capital invested in shipbuilding and armor plants, unless the law requires the program to be executed.

3. When the law fixes and defines such increase it may be expected that young men will enter the navy to make the service a life career.

4. Only when such a program is fixed by law can the requisite dockyard facilities be built and enlarged to meet the wants thus definitely prescribed.

5. By having such a policy defined by law, the prestige of Germany abroad is at once assured and consequently it is of the greatest importance in the political and commercial interests of the German Empire.

Comparing the present bill with that of 1898, it will be noticed that it is regarded as simply an increase in certain features over the Sexennate law. Under the head of the number of ships of which the navy shall consist the law does not state when the ships to be built must be finished, as was the case in the law of 1898. In the explanation as to how the measure is intended to be carried out, the period until the year 1916 is stated, but the governing council expressly recedes from the original plan and leaves the period somewhat in doubt, ostensibly as a concession to the arguments of the opposition that in such a long period of time it is impossible to foresee what technical, political, and financial events may transpire to make rigid adherence to the program undesirable. The fact that the law of 1898 was carried out before the expiration of the period contemplated, leaving comparatively little to be done in 1902 and 1903, the last years of the Sexennate period, has led the council to refrain from fixing the period until 1916 definitely, and the proposition is therefore only to provide the increase as the financial condition, etc., may from time to time render most expedient.

This concession may very easily result in the completion of the proposed increase at a much earlier date than 1916. But even if the proposed program should be closely adhered to, Germany's fleet would appear in the following years, thus:

Year.	Battleships.	Large cruisers.	Small cruisers.	Divisions of torpedo boats.
1900	17	10	29	12
1908	29	20	51	16
1916	38	20	45	16

It must be borne in mind that the total represented above in 1916 will be in addition to nearly all of the present fleet, and that many of these last will still be serviceable years after they reach the age limit prescribed by law. However, the scheme of building a substitute ship at a definite time and of immediately replacing any unit lost or destroyed is admirable in the interest of maintaining the naval force at a definite legal status. A careful consideration of the proposed bill would seem to indicate that it is proposed to build up the navy as fast as possible and not in sixteen or twenty years.

This increase in matériel necessitates a corresponding increase in personnel, which is provided for by a total increase at the end of twenty years of 35,551 officers and men. This total is to be attained by an annual increase of 89 officers and 1,687 men.

All the details connected with the expansion of the fleet have been worked out with mathematical accuracy, and the additions to the personnel consequent upon the largely augmented numbers of ships have also been settled with the same precision.

The full list of numbers of officers and men proposed for the years 1904 and 1920, is given as follows:

	1904.	1920.
Flag officers	19	32
Post captains	60	102
Commanders (Fregatten- und Korvetten-Kapitäne)	131	224
Lieutenant-commanders (Kapitänleutnants)	234	455
Lieutenants (Oberleutnants zur See)	382	647
Sublieutenants (Leutnants zur See)	274	628
Ensigns	....	304
Cadets	....	140
Engineer officers	180	427
Medical officers	182	341
Accountant officers	137	234
Rank and file	25,039	54,920

The formidable nature of the proposed extension of the German naval force is, perhaps, more evident from this table than from the program of new shipbuilding. The three grades of lieutenant-commander, lieutenant, and sublieutenant will together include upward of 1,700 names. Thirty years ago the number of lieutenants which sufficed for the wants even of the British navy was fixed at no more than 600.

The following tables are taken from the bill for the increase of the navy and show the proposed method of execution. Table I shows the *Ersatzbauten* (new ships to replace old ones) that will become due during the years 1901 to 1917. Table II shows the *Vermehrungsbauten* (new ships built for the increase of the fleet) that are required under the Naval Program of 1898 and this amendment. Table III recapitulates the data of the preceding tables. Table IV shows the proposed distribution of all *Ersatzbauten* and *Vermehrungsbauten* over the years from 1901 to 1916, inclusive.

TABLE I.

SHIPBUILDING PROGRAM FOR CARRYING OUT THE INCREASE.

Schedule of the *Ersatzbauten*[1] falling due in accordance with the Naval Program:	
Battleships and armored coast-defense vessels	17
Large cruisers	10
Small cruisers	29
Torpedo-boat divisions	12
Total, ships and torpedo-boat divisions	68

---

[1] New ships built to replace old ones.

List by name.

Battleships and armored coast-defense vessels.—Bayern, Sachsen, Württemberg, Baden, Oldenburg, Siegfried, Beowulf, Frithjof, Hildebrand, Heimdall, Hagen, Aegir, Odin, Kurfürst Friedrich Wilhelm, Brandenburg, Weissenburg, Wörth—17.

Large cruisers.—König Wilhelm, Kaiser, Deutschland, Kaiserin Augusta, Freya, Victoria Louise, Hertha, Vineta, Hansa, Fürst Bismarck—10.

Small cruisers.—Zieten, Blitz, Pfeil, Arcona, Alexandrine, Greif, Schwalbe, Sperber, Bussard, Falke, Seeadler, Condor, Cormoran, Geier, Meteor, Comet, Wacht, Jagd, Irene, Prinzess Wilhelm, Gefion, Hela, Gazelle, Niobe, Nymphe, C, D, E, F—29.

Torpedo-boat divisions.—Ten divisions, small boats; 2 divisions, large boats—12.

The *Ersatzbauten* for large ships fall due in the following years:

Year.	Battleships and armored coast-defense vessels, 17.	Large cruisers, 10.	Large ships (to be built yearly), 27.
1901	Bayern, Sachsen, Württemberg, Baden.	König Wilhelm, Kaiser, Deutschland.	7
1902			
1903			
1904			
1905			
1906	Oldenburg		1
1907			
1908		Kaiserin Augusta	1
1909			
1910			
1911			
1912	Siegfried		1
1913			
1914	Kurfürst Friedrich Wilhelm, Brandenburg, Weissenburg, Wörth, Beowulf, Frithjof.		6
1915	Hildebrand	Freya, Victoria Louise, Hertha, Fürst Bismarck.	5
1916	Heimdall, Hagen	Vineta, Hansa	4
1917	Aegir, Odin		2

TABLE II.

SCHEDULE OF THE REQUISITE *Vermehrungsbauten*.[1]

	Battleships.	Large cruisers.	Small cruisers.	Torpedo-boat divisions.	Total.
1. In accordance with the Naval Program			[2]1		1
2. For a third squadron	[3]10	[4]2	[4]6	[4]4	22
3. For a fourth squadron	[5]1		[6]2		3
4. For foreign service		[7]6	[8]7		13
Total	11	8	[9]16	4	39

[1] New ships built for the increase of the fleet.

[2] One small cruiser is still wanting to complete the number required by the Naval Program.

[3] 1 squadron flagship, 8 line-of-battle ships, 1 matériel-reserve ship.

[4] The two scouting groups (consisting each of 1 large and 3 small cruisers) and four torpedo-boat divisions belonging to one squadron.

[5] 1 matériel-reserve ship for the squadron of the *Brandenburg* and *Sachsen* class.

[6] The scouting groups belonging to the two divisions of armored coast-defense vessels heretofore comprised 2 instead of 3 small cruisers.

[7] Including 1 matériel-reserve ship.

[8] Including 2 matériel-reserve ships.

[9] Of these 15 are required by the amendment to the Naval Program and 1 in accordance with the Program.

TABLE III.

TOTAL NUMBER OF NEW SHIPS REQUIRED.

	Battleships.	Large cruisers.	Small cruisers.	Torpedo-boat divisions.	Total.
Ersatzbauten	17	10	29	12	68
Vermehrungsbauten	11	8	16	4	39
Total	28	18	45	16	107

TABLE IV.

DISTRIBUTION OF THE *Ersatzbauten* AND *Vermehrungsbauten* OVER A PERIOD OF SIXTEEN YEARS.

Year proposed.	Battleships (25).	Large cruisers (18).	Small cruisers (45).	Total.	Torpedo-boat divisions (16).	Remarks.
1901	2 Vermehrungsbauten[1]	1 Ersatzbau	1 Vermehrungsbau; 2 Ersatzbauten.	6	1 Ersatzdivision[1]	I. Building period 1901–1905.
1902	2 Vermehrungsbauten[1]	1 Ersatzbau	3 Ersatzbauten	6	1 Vermehrungsdivision[1]	
1903	2 Vermehrungsbauten[1]	1 Ersatzbau	2 Ersatzbauten	5	1 Vermehrungsdivision[1]	
1904	2 Vermehrungsbauten[1]	1 Vermehrungsbau[1]	3 Vermehrungsbauten[1]	6	1 Vermehrungsdivision[1]	
1905	2 Vermehrungsbauten[1]	1 Vermehrungsbau[1]	3 Vermehrungsbauten[1]	6	1 Vermehrungsdivision[1]	
1906	2 Ersatzbauten	1 Vermehrungsbau[2]	2 Vermehrungsbauten[2]	5	1 Ersatzdivision	II. Building period 1906–1909.
1907	1 Ersatzbau	2 Vermehrungsbauten[2]	3 Vermehrungsbauten[2]	6	1 Ersatzdivision	
1908	1 Ersatzbau	2 Vermehrungsbauten[2]	2 Vermehrungsbauten;[2] 1 Vermehrungsbau.	6	1 Ersatzdivision	
1909	1 Vermehrungsbau[3]	1 Vermehrungsbau[2]	1 Vermehrungsbau;[3] 2 Ersatzbauten.[3]	5	1 Ersatzdivision	
1910	1 Ersatzbau	2 Ersatzbauten	3 Ersatzbauten	6	1 Ersatzdivision	III. Building period 1910–1916.
1911	2 Ersatzbauten	1 Ersatzbau	3 Ersatzbauten	6	1 Ersatzdivision	
1912	2 Ersatzbauten	1 Ersatzbau	3 Ersatzbauten	6	1 Ersatzdivision	
1913	2 Ersatzbauten	1 Ersatzbau	2 Ersatzbauten	5	1 Ersatzdivision	
1914	2 Ersatzbauten	1 Ersatzbau	3 Ersatzbauten	6	1 Ersatzdivision	
1915	2 Ersatzbauten	1 Ersatzbau	3 Ersatzbauten	6	1 Ersatzdivision	
1916	2 Ersatzbauten		3 Ersatzbauten	5	1 Ersatzdivision	
Total				91		

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[1] For the active battle fleet.

[2] For foreign service.

[3] Non-active battle fleet.

For "Remarks," see next page.

REMARKS.

I. Building period 1901–1905.

Battleships:

10 *Vermehrungsbauten* for the completion of the active battle fleet by a squad of fully efficient battleships (1 fleet flagship, 8 line-of-battle ships, 1 matéri reserve ship).

Large and small cruisers:

Construction of the small cruiser still required by the Naval Program.

2 + 6 *Vermehrungsbauten* for the two scouting groups belonging to the ne squadron.

Ersatzbauten for the large and small cruisers not serviceable for war—

Large cruisers:—

König Wilhelm, *Kaiser*, *Deutschland*.

Small cruisers:—

Zieten, *Blitz*, *Pfeil*, *Arcona*, *Alexandrine*, *Greif*, *Schwalbe*.

Torpedo-boat divisions:

1 *Ersatz* division; 4 *Vermehrungs* divisions for the two torpedo-boat flotillas belonging to the new squadron.

II. Building period 1906–1909.

Battleships:

Ersatzbauten for the ships of the *Sachsen* class.

1 *Vermehrungsbau* (matériel-reserve for the squadron of the *Brandenburg* and *Sachsen* classes).

Large and small cruisers:

6 + 7 *Vermehrungsbauten* for foreign service; 2 *Vermehrungsbauten* for the completion of the scouting groups of the armored coast-defense divisions.

Ersatzbauten for the two small cruisers *Sperber*, *Bussard*.

Torpedo-boat divisions:

4 *Ersatz* divisions.

III. Building period 1910–1916.

Battleships:

1910–1914. *Ersatzbauten* for the 8 armored coast-defense vessels of the *Siegfried* class and for the *Oldenburg*.

1915–1916. *Ersatzbauten* for the 4 battleships of the *Brandenburg* class.

Large and small cruisers:

Ersatzbauten for the *Kaiserin Augusta*, the 5 ships of the *Hertha* class, the *Fürst Bismarck*, and for the small cruisers *Falke*, *Seeadler*, *Condor*, *Cormoran*, *Geier*, *Meteor*, *Comet*, *Wacht*, *Jagd*, *Irene*, *Prinzess Wilhelm*, *Gefion*, *Hela*, *Gazelle*, *Niobe*, *Nymphe*, *C*, *D*, *E*, *F*.

Torpedo-boat divisions:

7 *Ersatz* divisions.

Under the new bill Germany's home battle fleet will be composed of 34 battleships, 8 large cruisers, 24 small cruisers and 80 torpedo boats. These are to be organized as shown in the diagram.[1] In consequence of the proposed increase the following principles are to apply to the keeping in commission of the home fleet:

1. The first and second squadrons shall form the active battle fleet, the third and fourth squadrons the non-active battle fleet.

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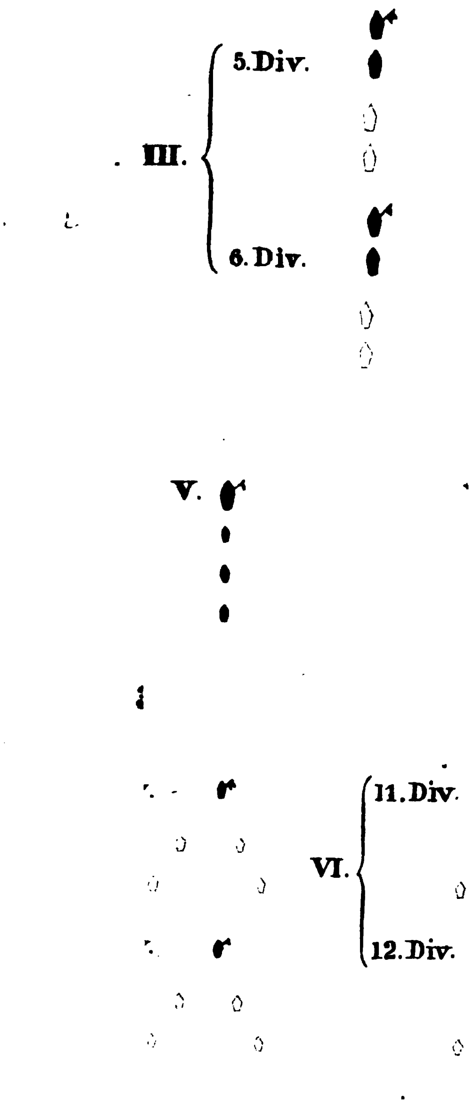
[1] The reserve is not shown in the diagram.

in Home Fleet



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2. All the battleships and cruisers of the active battle fleet and one-half of those of the non-active battle fleet shall be kept constantly in commission.

3. Some of the ships of the non-active battle fleet which are out of commission shall be placed in commission temporarily for the purpose of manœuvres.

NOTE.—The naval bill was passed by the Reichstag June 12, 1900, and will go into effect as soon as approved by the Emperor. The original bill provided for 38 battleships, 20 large cruisers, and 45 small cruisers. The bill as finally passed by the Bundesrath and Reichstag provides for 38 battleships, 14 large cruisers, and 38 small cruisers. It also places the life of a small cruiser at 20 years instead of 15 years.

ITALY.

The total naval budget for 1900–1901 amounts to 122,174,671 lire. In the report of the general budget committee on the project of the principal credits for naval construction it is stated that Italy has at present on the stocks or in a more or less advanced state of construction the following list of ships:

First-class battleships.—Emanuele Filiberto, Ammiraglio di Saint-Bon, Regina Margherita, Benedetto Brin.

Armored cruisers.—Francesco Ferruccio, Garibaldi, Varese.

Small cruisers.—Agordat, Coatit, Puglia.

Ten torpedo-boat destroyers and 3 first-class torpedo boats.

The aggregate cost of these ships, including complete equipment, is estimated at 146½ million lire.

To these vessels already building Admiral Bettolo's naval program adds two first-class battleships. The cost of construction and armament of the latter is estimated at 40 million lire, so that the total amount required for the four years from 1899 to 1903 is, in round numbers, 186 million lire.

The funds remaining available at the beginning of the fiscal year 1899–1900 were 20,650,000 lire; the normal credits of the budget for the five years from 1899 to 1904, for construction of ships, are 120,400,000 lire; hence there is a discrepancy of about 45 million lire between the estimates and the credits. The project provides for 40 of the 45 million by allowing an additional credit of 10 million a year under the respective head of the budget for the present year and three succeeding years. The remaining deficit of 5 million the minister of marine hopes to provide for by economies in the budget.

According to the text of the draft of law agreed upon between the minister of marine and the parliamentary committee, beginning with the financial year 1899–1900, and for the three succeeding years, including the financial year 1902–1903, an annual extraordinary expense of 10 million lire is authorized for shipbuilding, to be entered under extraordinary expenses, in addition to the amounts placed on the budget for the same purpose under the head of ordinary expenses. The extraordinary expenses and the ordinary credits for shipbuilding during the said four years are to be employed to hasten the completion of the ships now under construction or in process of equipment; as far as the terms of the contracts with private firms permit, and to the laying down of the two first-class battleships.

The amounts to be placed annually on the naval budget, under the head of ordinary expenses for shipbuilding, including the quotas which remain to be entered on the amounts authorized by the law of July 28, 1891, and which will be transferred to the head of ordinary expenses, are fixed for the fiscal years from 1899 to 1904 as follows:

For the fiscal year—	Lire.
1899–1900	23,500,000
1900–1901	24,500,000
1901–1902	24,400,000
1902–1903	24,000,000
1903–1904	24,000,000

Beginning with the present fiscal year, including the residue of the budget of 1898–99, and up to and including the fiscal year 1903–04, there will be available for shipbuilding the sum of 141,049,446 lire, to which must be added the extraordinary expense authorized under the present project of law, 40,000,000 lire, or a total of 181,049,446 lire. With this total sum the following program is to be carried out:

	Lire.
1. Construction of 2 new battleships	40,000,000
2. Completion of equipment of battleships *Filiberto* and *Saint Bon*	3,060,990
3. Completion of construction of *Benedetto Brin*, *Regina Margherita*, and *Ferruccio*	72,392,700
4. Equipment of cruisers *Puglia*, *Agordat*, and *Coatit*	1,656,161
5. Completion of *Garibaldi* and *Varese*	19,959,440
6. Completion of 10 destroyers and 3 torpedo boats	12,894,550
7. Construction of boats and craft for harbors and navy-yards	5,500,826
8. Additional expense for labor	30,502,000
Total	185,966,677

which is 4,917,231 lire more than the sums provided, and which amount the minister of marine proposes to provide by economies in the budget.

JAPAN.

The Naval Program of 1895 provided for the building of 54 vessels by 1901 and 63 more by 1906, making a total of 117 war ships. These were divided as follows: 4 battleships, 4 first-class armored cruisers, 3 second-class armored cruisers, 2 third-class armored cruisers, 15 torpedo cruisers, 89 torpedo boats.

All these vessels are at the present either completed or in process of construction, and it is probable that a new program will shortly be decided. The budget for 1900 amounts to 46,946,193 yen. In addition to the yearly budget there is a special fund for the maintenance of vessels of the Japanese navy which was enacted by the Diet of 1898–99. The act creating this fund is as follows:

> Art. I. A fund is hereby set aside for the maintenance of vessels of the navy, and such fund shall be treated as a special account, separate from the general account.
>
> Art. II. Thirty million yen is hereby appropriated for the fund from the indemnity fund kept in special account.
>
> Art. III. At the beginning of each fiscal year from 1904 a sum equal to the aggregate of the following percentages of the cost of vessels on the navy list the last day of the preceding fiscal year shall be added to the fund from the general finance: For protected vessels, 3.9 per cent; for unprotected vessels, 5.4 per cent; for torpedo craft, 6.5 per cent.
>
> Art. IV. When vessels have reached the age shown in the following table no further annual payments shall be made on their account: Protected vessels, 25 years; unprotected vessels, 18 years; torpedo craft, 15 years.
>
> Any vessel struck from the navy list after the year 1904, before having reached the age prescribed in the above table, a sum equal to the total amount of the annual payments remaining for such vessel shall be paid into the fund from the general finances.
>
> Art. V. The fund shall be held in trust by the treasury department, and the interest accruing shall be added to it.
>
> Art. VI. The interest from the fund and the annual payments made upon account of the deterioration of vessels shall be used for building vessels to recruit the navy, but the original fund of thirty million yen shall be left intact.
>
> Art. VII. The Government shall each year prepare estimates of the income and disbursement of the fund, and shall lay it before the Diet, together with the budget.

In regard to the proposed new construction for the Japanese navy the following extract is taken from the Jiji Shimpo of May 5, 1900:

> It is now high time, naval officers say, for Japan to plan the third naval expansion scheme, and we hear that an item for construction of new vessels will appear in the budget of the coming fiscal year. As to the program of new naval expansion the naval authorities undoubtedly have plans, but the difficulty is to make the minister of the treasury consent to the disbursement of the required sum, and it is impossible to foresee in what form the program will appear in the coming Diet, because of the uncertainty of the result of the conference between the departments of the navy and treasury. Thus far the minister of the treasury seems to have practically consented to the disbursement for new construction of two million yen in addition to the three million yen, interest of the naval supplementary fund, provided by the Diet two years ago. But five million a year is quite an inadequate sum. Many officers are of the opinion that if the treasury can not afford to allot more money to the navy it is better to build a number of destroyers, since the most powerful battleship can not escape surrounded by over ten destroyers. It seems that during the late manœuvres valuable experiments were made, which indicated the great offensive efficiency of vessels of the destroyer class, and as it costs only 500,000 yen to build one destroyer this opinion will probably be generally approved by naval officers. As it has already been decided to build six destroyers instead of one torpedo tender, there is no doubt that demand will be made in the coming Diet for the construction of more destroyers. Whatever may be the program of the new naval expansion planned by the naval authorities, they will hesitate to demand a large appropriation for new construction, as it will be very difficult to obtain the consent of the Diet, and it is probable that not more than five million yen will be thus expended by the coming Diet.

RUSSIA.

Early in 1898, following the example of the European powers, Russia formulated a program of new construction. For this purpose a sum of 90 million roubles was set apart for the completion in six years, ready for sea, of 10 armored cruisers, 10 second-class cruisers, and 20 destroyers. This program was in addition to the annual program outlined by the naval estimates.

This program was changed for various reasons, and it was finally decided to build 8 battleships, 8 large cruisers, and 20 destroyers with the amount appropriated. To complete these ships in the given time, it was necessary to place contracts for several of them abroad, but at the same time care was taken to reserve enough of the money to keep the shipbuilding yards at home fully occupied in completing their share of the program and to develop the existing Government factories for the production of guns and armor. The present output of these latter, although much increased, is still insufficient to keep pace with the acceleration in the rate of ship construction in that country.

Notwithstanding the fact that the progress made with existing programs has not been as rapid as was expected and that her naval budget has steadily increased from 29 million dollars in 1897 to 45 millions in 1900, it is currently reported that the Russian Government has in preparation and will shortly announce a new and extensive program for the increase of her fleet.

SPAIN.

The following royal decree in regard to the Spanish navy, together with the argument of the minister of marine, is taken from the *Revista General de Marina*, June, 1900:

EXPOSITION.

MADAME: There is no doubt that Spain for her existence requires a navy proportionate to the country's available resources for maintaining it in effective condition, that such navy should conform to the new conditions for naval matériel imposed by the loss of our colonial possessions, and that it should be capable of assisting effectually in the defense of our territory and count as a factor among military forces, and it is well known that our present navy does not answer any one of these requirements.

It is imperative to take energetic steps for remedying this state of affairs by laying down a definite basis for the creation of matériel of military value and of personnel that will in time be able to handle it efficiently, when it has become inured to life on the sea and been trained in the management of the weapons of warfare that are indispensable for the effective operation of a squadron; and the first step for attaining these results must be to discard all matériel which is worthless from a military standpoint, which needlessly absorbs a considerable part of the budget funds and serves no other purpose than to maintain a show of strength which will be a source of terrible disillusion when the time comes for putting it to the test, and which calls forth just criticisms on the part of those who are competent to judge of our naval strength.

One of the greatest and most widespread evils to which a long period of national calamities has led us is that we are easily satisfied with the appearances of the service and the purely external form of our institutions, without paying sufficient heed to the true substance and efficacy which may be expected from the exercise of their functions; and while many organisms of the state suffer from this deep-rooted evil the former, subjected to the severe test of a foreign war, have suffered greater punishment, paying with the sacrifice of their blood and, in some instances, with heroic martyrdom for such sad mistakes.

The undersigned minister believes it his duty not to carry to the next naval budget, nor to maintain on the present one, any ships that are not of positive value for the military service of a squadron, and to state their exact number and properties, selling or breaking up everything worthless in that respect. For it is obvious that to maintain vessels that possess no fighting value, nor can assist war ships in battle, nor render services in time of peace is an unjustifiable expense.

Hence the first step—the most natural and most easily understood by ordinary common sense, yet not the least painful among the many steps which will be necessary in order to reconstruct a navy truly worthy of that name—must be an examination of the floating matériel which we possess at present and its immediate reduction by whatever is obviously worthless for the necessities of the naval service.

The *Pelayo*, with the modifications recently made in the protection of her battery and in her boiler system, machinery, and armament, is a second-class battleship of great offensive power by reason of her armament, and in good condition. With a few further repairs and reduction of the woodwork she will be an efficient war ship, in condition to render good services in conjunction with others of the same class.

The *Carlos V*, though sometimes classed as a battleship, can in reality not be considered anything more than an imperfectly protected cruiser, owing to the lack of 15-centimeter armor, and is at the same time of small offensive power; but her speed of 19 knots and her radius of action render her of undoubted value in a war, under the protection of other battleships, as long as she preserves her speed.

The *Numancia* and *Vitoria*, whose protection is slight, though well distributed, and which have only one engine, a speed of not exceeding 11 knots, and scant armaments, may still be used for coast defense or attacks upon poorly armed cities or ports.

The *Rio de la Plata* and *Extremadura*, being cruisers without lateral protection and without armament to speak of, can be employed only on missions in time of peace; for if they were employed in time of war, though only in the pursuit of hostile merchant vessels, they would soon be captured and destroyed by armored and protected cruisers of greater speed than 19 or 20 knots, which is all they are able to develop, and they could only fulfill, in an imperfect manner, the functions of dispatch boats in coast defense and under the protection of fortified places.

The *Alvaro de Bazán*, *Maria de Molina*, and *Marqués de la Victoria* also lack military value; but if their conditions are improved so as to endow them with great speed, they might be utilized as dispatch boats and for missions in time of peace, under the same terms as the preceding ones; also to assist the army in quelling civil disturbances, or to reduce unfortified points or very inferior ships.

The *Nautilus* is being used at present only as a training ship for midshipmen, and must continue to be employed as such until some other vessel, equipped both for sailing and steam power, is acquired to replace her to good advantage, after which she may serve as training ship for midshipmen, boatswains, and seamen, in place of the *Villa de Bilbao*, which can no longer navigate, but has to be kept in commission temporarily to discharge the service of instruction, though in a very imperfect manner.

The *Urania* fulfils the functions as surveying vessel, for which purpose she is well adapted, and should be so employed until the completion of this tedious work, which does honor to our navy by the thoroughness and conscientious manner in which it is being done.

The *Giralda*, thanks to her good condition and speed, though devoid of military value and defective in several respects as dispatch boat, can nevertheless do duty in missions of peace and for international services which the navy may have to perform.

The *Infanta Isabel*, also devoid of military value, is suitable for service in the Canaries, on the Gold Coast, and our colonies in Guinea, and must continue to serve in that capacity as long as there is no other ship of military efficiency to fulfill that function.

Similar considerations make it advisable to retain the *Nueva España*, the generous gift of our Mexican brethren.

The destroyers and torpedo boats can, for the greater part, be utilized for war purposes. But all should be carefully examined in order to classify them and utilize those which are found in good condition, assigning the same to service as gunnery, machinery, and torpedo training ships for practice, as well as cruises on the sea. But this requires a thorough technical examination of each one. To make a final decision now without such examination would be unpardonable carelessness. This applies to the following: *Destructor*, *Terror*, *Audaz*, *Osado*, *Proserpina*, *Halcón*, *Azor*, *Ariete*, *Rayo*, *Orión*, *Barceló*, *Ordóñez*, *Acevedo*, and *Habana*, which, with two tenders for service on the coasts of Guipúzcoa and two more for service in the Balearic Islands, gunboats *Concha* and *Magallanes*, and a pontoon for service at Fernando Po, the *Ponce de León*, *Perla*, and *Mac-Mahón* for the protection of fisheries in the Guadiana, Miño, and Bidassoa rivers, which on account of their shallow bottoms can not be entered by vessels of any other class, the *Lepanto* as torpedo, gunnery, and machinery training ship, the *Asturias* as a naval school, gunboats *Vasco*, *Nuñez de Balboa*, *Hernán Cortés*, and the *Nueva España*, already mentioned, designed for harbor service in the departamentos, and cruisers *Cardenal Cisneros*, *Princesa de Asturias*, and *Cataluña*, the latter under construction, will constitute our total strength afloat, viewed in the most generous spirit of prevision, and greatly stretching our needs for missions and services of peace, for maintaining civil order, and for our relations with the African coasts, and without discarding from the naval forces anything unless from informal hearsay and technical information from various sources it is known to be unquestionably worthless, even prejudicial, on account of the personnel that must be assigned to it and the material it consumes, even though reduced to a minimum, without being able to cruise nor render services of any kind.

This applies also to the *Alfonso XIII*, similarly defective as the ill-fated *Reina Regente*, of 4,826 tons. This ship being without vertical protection of any kind, having only a protective deck, lacking stability, with engines badly mounted, a speed of scarcely 12 knots, it is the general opinion of the technical authorities of the navy that she should not be allowed to go to sea unless extensive and costly repairs are made, so as not to expose her crew to probable disaster. She would only be an impediment and obstacle for any squadron or naval division, nor can she be utilized for defensive operations, nor on missions of peace, for which purpose, moreover, there are on hand sufficient ships in proportion to the resources which should be assigned to such services under a reasonable naval budget.

The *Alfonso XII*, *Temerario*, *Vicente Yáñez Pinzón* and *Martín Alonso Pinzón* are ships without military value of any kind, lacking protection for their sides as well as their armaments, engines, and boilers, and could therefore be promptly destroyed not only by modern guns, but even by obsolete ones; they have no speed and can be utilized at best for missions of peace and the unprofitable office of pursuing contraband, while absorbing to no advantage whatever, the same as the *Marqués de la Ensenada*, a good portion of the naval budget; they are the subject of grave and well justified censure, and serve no other purpose than to figure in the list of an absolutely fictitious squadron.

The *Conde de Venadito* and *Isabel II* are small ships and no longer in condition to go to sea. The Centro Consultivo (advisory board) has suggested the possibility of keeping them, plans having been made for renewing their boilers; but upon examination of the contract which it was intended to carry out, it is found that the boilers which would have to be installed on board these ships would cost 500,000 pesetas, to which must be added the expense of tearing up part of the decks and rebuilding them after the new boilers have been installed, which is estimated at about 60,000 pesetas for each of the ships, and it would take a year before they could be ready. As to employing them for quelling civil disturbances, experience has shown that for such purposes ships of less tonnage are more suitable.

The paddle-wheel transport *General Valdés* is worthless. It would require considerable expense in repairs merely to enable her to leave port. She consumes enormous quantities of coal and is, in the unanimous opinion of the corps of the navy, inefficient for the services which she is intended to render.

The torpedo boats *Retamosa*, *Rigel*, *Ejército*, and *Castor*, gunboats *Eulalia*, *Pilar*, *Condor*, *Aguila*, *Cuervo*, and *Tarifa*, and tenders *Concha*, *Gaditana*, *Pez*, *San Mateo*, *Mariana*, *Ardilla*, and *Guinda* are deemed, in the unanimous opinion of superior officers and other competent men who are well acquainted with their condition, absolutely unserviceable.

It is not the object of this decree to effect economy, but to apply the credits allowed in the present budget to better advantage, and therefore what remains of the personnel and matériel of the above-named ships will be employed toward completing the crews of the *Pelayo*, *Carlos V*, *Numancia*, and *Vitoria*, as far as their present accommodations permit or as far as they can prudently be increased, for officers as well as machinists, boatswains, and other classes, who are to devote themselves to the instruction of their crews in navigation and practice of every kind.

But it is imperative at the same time to provide for the instruction of the officers and men who are to constitute in the future an efficient personnel, well trained and inured to the sea, designed to command and man the future squadron, without the great expense necessitated by maintaining a number of warships constantly under steam, and for that purpose it is expedient to acquire, for the present, two ships equipped for both sailing and steam power, of about 2,000 tons each, to be fitted so as to enable them to receive on board the greatest possible number of officers and subaltern classes, for the purpose of visiting the principal navy-yards of Europe and extending their cruises to South America, the Pacific, the coasts of the African continent, the Suez Canal, and the waters of India and China, and to the acquisition of such ships should be assigned the proceeds of the sale of vessels which may be declared unserviceable, or the funds turned into the treasury from that source, subject to the law of accounts.

The personnel which, under this reorganization of the naval service is not assigned to sea service, which will be limited, will constitute a well-justified charge upon the country, and in anticipation of a future increase of the naval matériel such personnel should remain at the centers of instruction of the navy and its shipyards and should therefore be assigned to these naval establishments and the torpedo, gunnery, and machinery school, until the time arrives when the strength of our navy is placed on a definite footing through the intervention of the Cortes.

This is the first step to be taken for accomplishing the reorganization of a navy capable of fulfilling the requirements expressed at the beginning of this preamble, and it should be followed by further measures bearing upon the revision of the fundamental law of the navy, so as to make promotion to the rank of admiral elective, to decrease the age of retirement from active service, to enforce the terms of embarkation, and to define the manner of effecting the classification and selection of the personnel of the different corps of the navy, the new regulation for the subaltern classes and their passive rights, the new constitution for the grading of reserves and their duties, the reorganization of the administration of the navy-yards by separating the technical and industrial from the military and naval administration, the "decentralization" and simplification of the central administration of the navy, the creation of naval reserves, and other measures of reorganization which for their realization require the cooperation of the country and the good will of all parties.

Based on the foregoing considerations and substantially in conformity with the report of the Centro Técnico Consultivo, which has pronounced its opinion on the basis and antecedents referred to it for its examination and opinion, the undersigned minister has the honor of submitting to Your Majesty for approval the following decree.

FRANCISCO SILVELA.

MADRID, *May 28, 1900.*

ROYAL DECREE.

In conformity with the recommendations of the minister of marine, with the approval of the council of ministers, in the name of my august son, King Alfonso XIII, and as Queen Regent of the Kingdom, I decree as follows:

ARTICLE 1. The ships hereinafter enumerated, after taking out those whose hulls can be utilized as floating depots for coal, ammunition, or matériel for submarine defense, shall be dismantled and struck from the lists of the navy, and immediate steps shall be taken for selling them or breaking them up:

Cruisers: *Alfonso XIII*, *Alfonso XII*, *Conde de Venadito*, *Isabel II*, *Marqués de la Enseñada*, and *Temerario.*

Torpedo gunboats: *Martín Alonso Pinzón*, *Vicente Yáñez Pinzón*, and *Marqués de Molins.*

Transport: *General Valdés.*

Gunboats: *Eulalia*, *Pilar*, *Condor*, *Aguila*, *Segura*, *Curro*, and *Tarifa.*

Torpedo boats: *Retamosa*, *Rigel*, *Ejército*, and *Castor.*

Tenders: *Concha*, *Gaditana*, *Murciana*, *Ardilla*, and *Guinda.*

ART. 2. Of the remaining ships, the *Numancia*, *Vitoria*, and *Infanta Isabel* shall be struck from the list when it may become necessary to renew their present boilers or when they shall require other extensive repairs.

ART. 3. The credits allowed under the present budget for the maintenance of the personnel and the ships the dismantling of which is ordered in article 1, shall be employed toward completing and increasing the crews of the *Pelayo*, *Carlos V*, *Numancia*, *Vitoria*, and *Nautilus*, as far as their present quarters permit, or as far as additional ones can prudently be built, for officers as well as machinists, boatswains, gunners, and other subaltern classes, who are to devote themselves to the instruction of their crews in constant cruises and practice of every kind.

ART. 4. On board the cruiser *Lepanto* shall be established a torpedo, gunnery, and machinery training and practice school which, together with the ships mentioned in the foregoing article, shall contribute to the instruction of the personnel.

ART. 5. With the proceeds of the sale of the ships enumerated in article 1, and the savings thereby effected in the budget, or with the funds turned into the treasury from these sources, subject to the formalities required by the law of accounts, immediate steps shall be taken for the acquisition or construction, in Spain or abroad, of two ships equipped for sailing and steam power, of about 2,000 tons each, which ships, fitted out so as to be able to accommodate the greatest possible number of officers and subaltern classes, shall proceed in the shortest possible time to visit the principal navy-yards of Europe, extending their cruises to South America and returning home by way of the Pacific Ocean, the waters of Australia and India, and the Suez Canal.

ART. 6. Considering that the personnel of the navy will be only temporarily affected by these modifications, as long as the strength of the new navy has not been definitely decided upon and the composition of the different corps of the navy regulated in accordance therewith, the present status shall not be increased, and the chiefs, officers, and subalterns who can not be given employment in the service afloat shall be assigned to the navy-yards, the centers of instruction, and the torpedo, gunnery, and machinery training school, where they shall receive in full the pay to which they are entitled in accordance with such assignments.

Art. 7. The minister of marine is authorized, with the approval of the minister of the treasury, to decide such questions as may arise when the dispositions made necessary for carrying out the terms of this decree are put in force, and a report thereof shall be made to the Cortes at their first session.

Given at the palace on the 28th day of May, 1900.

Maria Cristina.

Francisco Silvela,
Minister of Marine.

AUSTRIA.

The Austrian naval estimates for the year 1901 for ordinary expenses amount to 28,521,660 crowns (an increase of 2,965,610 crowns over the preceding year) and for extraordinary expenses to 14,969,160 crowns (an increase of 1,058,710 crowns over 1900).

The ordinary estimates include, among others, the following items: Last installment for construction of torpedo cruiser *Aspern* ("B"), 2,350 tons, to replace *Helgoland;* third installment for torpedo cruiser "C," 2,350 tons, to replace *Fasana;* second installment for ram cruiser "E," 7,300 tons, to replace *Radetzky;* last installment for small mine tender of 200 tons; first installment for battleship "A," 10,000 tons, to replace *Laudon.*

The extraordinary estimates include, among others, appropriations for armaments of ships under construction and ammunition therefor; mines, torpedoes, and torpedo nets; work at coaling and torpedo station Teodo; last installment for enlarging magazines at Vallelunga and mine establishment at Fisella; construction of magazine at Fisella for torpedo ammunition and gun cotton; construction of five fire proof magazines at the equipment arsenal; last installment for cruiser *Kaiser Karl VI* ("D"), 6,250 tons; fourth installment for coast-defense vessel of 8,340 tons (Battleship I); third installment for Battleship II, 8,340 tons; second installment for Battleship III, 8,340 tons.

DENMARK.

The ordinary naval budget for 1900 amounts to 7,100,000 crowns. Under new construction is an item of 514,000 crowns for the completion of the battleship *Herluf-Trolle*, which was recently launched, and a first credit of 371,000 crowns for the construction of a new battleship of the same type.

HOLLAND.

The naval budget for 1900 amounts to 15,959,262 florins, of which sum 6,755,905 florins is devoted to new construction. The increase of the fleet has been given much attention, and a building program extending over a period of ten years is projected. In addition to the present fleet, the new program proposes 4 more battleships of the *Koningin-Regentes* type, one of which is now building; 2 smaller battleships for interior waters, 3 monitors, 14 gunboats, 21 seagoing torpedo boats, and 12 smaller torpedo boats. The estimated cost of this program, including the *Koningin-Regentes* and sister ship building, is 41,082,000 florins. By authorizing each year 4,200,000 florins for new construction the above program will be finished in 1909. All details have been carefully worked out and the building evenly distributed over the proposed period.

SWEDEN.

The naval budget for 1900 amounts to 20,619,600 crowns. A credit of 5,376,000 crowns is allotted for construction of the three new battleships of the same type and dimensions as the first-class battleship *Dristigheten*, building at Gothenburg.

Four million nine hundred and twenty thousand crowns is estimated as necessary to thoroughly overhaul and modernize the coast-defense battleships *Svea*, *Gota*, and *Thule*, of which 2,500,000 crowns is to be expended in 1900 and the remainder in 1901. Besides the above credits, others are inscribed for the completion of the *Dristigheten*, the corvette *Jarramas*, the torpedo cruisers *Clas-Uggla* and *Psilander*, and seven torpedo boats.

II.

NOTES ON SHIPS AND TORPEDO BOATS.

By Lieutenant CHARLES C. MARSH, United States Navy,
Staff Intelligence Officer.

BUILDING, ORDERED AND PROPOSED.

CONSTRUCTION ABROAD.

Since the last report of the office, the various powers have been active in preparing their shipbuilding programs for the coming year, and in some cases a program for a period of years. Construction has been actively pushed, and vessels launched and tried.

There have been no radical departures in the way of new designs, except in the case of Italy, whose 8,000-ton battleships, with an armament of 8-inch guns, mark a most interesting change.

SHIPS LAID DOWN SINCE NOVEMBER, 1899

ENGLAND.

Name.	Class.	Tonnage.	Place.	Date.
Montagu[1]	Battleship, first class	14,000	Devonport	Nov. 23, 1899
Albemarle[1]	do	14,000	Chatham	Jan. 1, 1900
Leviathan[2]	Armored cruiser, first class.	14,100	John Brown & Co., Clydebank, Glasgow.	Dec. 1, 1899
Essex	do	9,800	Pembroke	Jan. 2, 1900
Kent	do	9,800	Portsmouth	Feb. 1, 1900
Espiegle[3]	Sloop	1,070	Sheerness	Jan. 8, 1900
Fantome[3]	do	1,070	do	Do.

[1] Duncan class. [2] Drake class. [3] Improved Condor class.

FRANCE.

"A"	Armored cruiser, first class.	12,410	Brest	To be laid down.

RUSSIA.

Ten torpedo destroyers of 350 tons each were ordered from the Neva Works in November, 1899.

"A," cruiser, 6,000 tons, was to be laid down at Sevastopol in March, 1900.

"B," "C," "D." Three similar cruisers to be laid down at same place later in the year.

Battleships "A" and "B" were reported laid down at St. Petersburg on the launching of the *Pobieda* (battleship), and *Aurora* (armored cruiser), May 24, 1900.

Admiral Budtakoff, coast-defense ship, 6,000 tons, of the *Apraxine* type, laid down at St. Petersburg.

Four transports, to be laid down at Nicolaeff for the Black Sea service.

GERMANY.

Name.	Class.	Tonnage.	Place.	Date.
"G"[1]	Battleship, first class	11,081	Imperial Yard, Wilhelmshaven.	
"H"[1]	do	11,081	Vulcan Works, Stettin	
"I"[1]	do	11,081	Germania Works, Kiel	
"D"[2]	Small cruiser	2,800	do	Nov. —, 1899
"E"[2]	do	2,800	Bremen	
"F"[2]	do	2,800	Germania works, Kiel	Nov. —, 1899
"K"	Gunboat	[3]900	Danzig Yard	Apr. —, 1900

[1] Kaiser Friedrich III class. [2] Gazelle class. [3] Probably.

"B," armored cruiser, sister to the *Prinz Heinrich*, 8,000 tons, to be laid down at the Imperial dockyard, Kiel.

Ersatz Kaiser, battleship, to be laid down in 1900, to replace the *Kaiser*.

Ersatz Deutschland, battleship, to be laid down in 1901, to replace the *Deutschland.*

Three "high sea" torpedo boats, to be laid down at Krupp's, Kiel.

ITALY.

"A," one of the four 8,000-ton battleships, is reported to have been ordered from the arsenal at Spezzia.

AUSTRIA.

"III," coast-defense ship, 8,340 tons, to replace the *Erzherzog Albrecht.*

BRAZIL.

Four torpedo cruisers, 1,060 tons, of the *Tamoya* class, ordered from Krupp's Germania Works.

JAPAN.

"1," cruiser, third class, 3,000 tons, ordered to be built at the dockyard at Yokosuka, Japan.

"2," cruiser, third class, 3,000 tons, ordered to be built at the dockyard at Kure, Japan.

SWEDEN.

"A," battleship, 3,650 tons, laid down at the Kockum Works, Malmo.

"B," battleship, 3,650 tons, laid down at the Bergsund Works, Stockholm.

"C," battleship, 3,650 tons, laid down at the Motala-Lindholm Works, Gotaborg.

SHIPS LAUNCHED SINCE LAST REPORT (NOVEMBER, 1899).

ENGLAND.

Name.	Class.	Tonnage.	Built at—	Begun—	Launched—
Sutlej	Cruiser, first class	12,000	Clydebank	Aug. 15, 1898	Nov. 18, 1899
Stag	Torpedo-boat destroyer	300	Thornycroft		Do.
Cressy	Armored cruiser	12,000	Glasgow	Oct. 12, 1898	Dec. 4, 1899
Assurance	Tug	300	Paisley	July 27, 1899	Dec. —, 1899
Cracker	do	700	Glasgow	Feb. 10, 1899	Dec. —, 1899
Pandora	Cruiser, third class	2,200	Portsmouth	Jan. 3, 1898	Jan. 17, 1900
Sheerwater	Sloop	980	Sheerness	Feb. 1, 1899	Feb. 10, 1900
Vestal	do	980	do	do	Do.
Mutine	do	980	Birkenhead	Nov. 2, 1898	Mar. 1, 1900
Enterprise	Tug	300	Paisley	Aug. 30, 1899	Feb. 28, 1900
Ostrich	Torpedo-boat destroyer		Govan		Mar. 22, 1900
Myrmidon	do	300	Jarrow		June —, 1900
Aboukir	Armored cruiser	12,000	Glasgow	Nov. 8, 1898	May 16, 1900

FRANCE.

"213"	Torpedo-boat		Havre		Nov. 3, 1899
Montcalm	Armored cruiser	9,517	La Seyne	Jan. 25, 1898	Mar. 27, 1900
Yatagan	Torpedo-boat des	311	Saint Nazaire		Mar. 20, 1900
Pique	do	311	Havre		Mar. 31, 1900
Fauconneau	do	303	Normand		Apr. 2, 1900
Dupleix	Armored cruiser	7,700	Rochefort	Jan. 18, 1899	Mar. 28, 1900
Gloire	do	10,014	Lorient	Sept. 5, 1899	June 27, 1900

RUSSIA.

Skat	Torpedo-boat des	350	Elbing		Oct. 21, 1899
Kit	do	350	do		Nov. 30, 1899
Askold	Armored cruiser	6,500	Kiel		Mar. 15, 1900
Pobieda	Battleship	14,500	St. Petersburg	Aug. 1, 1898	May 24, 1900
Aurora	Armored cruiser	6,630	do	Oct. 31, 1896	Do.
Bayan	do	7,800	La Seyne	Mar. —, 1899	June —, 1900

GERMANY.

"S-100"	Torpedo-boat des		Elbing		Apr. 24, 1900
"S-97"	do		do		Dec. 16, 1899
"S-93"	do		do		Jan. 31, 1900
Prinz Heinrich	Armored cruiser	8,880	Kiel	Dec. 1, 1898	Mar. 23, 1900
Kaiser Barbarossa	Battleship, first-class	11,081	Danzig	Aug. 3, 1898	Apr. 14, 1900

ITALY.

Frecchia	Torpedo-boat des	320	Elbing		Nov. 23, 1899

Ships launched since last report (November, 1899)—Continued.

HOLLAND.

Name.	Class.	Tonnage.	Built at—	Begun—	Launched—
Scylla	Torpedo boat	140	Yarrow		June 16, 1900
JAPAN.					
Niji	Torpedo-boat des		Yarrow		Dec. 16, 1899
Usugumo	do		Thornycroft		Jan. 16, 1900
Iwate	Armored cruiser	9,700	Elswick		Mar. 29, 1900
Chihaya	Torpedo gunboat	1,250	Yokosuka		May 26, 1900
NORWAY.					
Norge	Battleship, second-class.	3,850	Elswick		Mar. 31, 1900
Eidsvold	do	3,850	do	—— —, 1899	June 14, 1900
CHINA.					
Kienngan	Cruiser		Foochow		Mar. 3, 1900
TURKEY.					
Saidi Chadi	Gunboat		Ismidt		—— —, 1900
SPAIN.					
Extremadura	Cruiser	2,030	Cadiz	Feb. 22, 1899	Apr. 19, 1900

STEAM TRIALS.

ENGLAND.

The Admiralty has directed that in future when a vessel is built at a private dockyard and is sent to a naval port for her official trials the contractors are to be allowed to subject the vessel to a basin trial of her machinery, and also a preliminary trial at sea, before she commences her official trials.

Hitherto it has frequently happened that a ship has been sent on a thirty hours' trial without the engineering staff having a fair opportunity to make the necessary adjustments in the machinery. The Admiralty also directs that in future every vessel is to have a basin trial after her machinery has been opened out for inspection, on completion of her official trials.

BATTLESHIPS.

GOLIATH.

The eight hours' full-power trial of the *Goliath*, completing her series of trials, took place in the English Channel on November 22, when the following satisfactory results were attained: With the ship practically on an even keel—her water draught being 26 feet forward and aft—and steam at a boiler pressure of 290 pounds per square inch, the revolutions of the starboard and port engines were 108.1 and 109.8 per minute, and the power developed by them 6,998 and 6,920, respectively, or a grand total of 13,918 indicated horsepower, being 418 in excess of that contracted for—an eminently satisfactory result—both engines and boilers having worked remarkably well, the coal consumption on the trial having been 1.91 pounds per indicated horsepower per hour, and the speed of the ship in the same time 18.4 knots.

As a battleship, or any class of war ship, is seldom called upon to exceed the normal rate of steaming attained by her on a thirty hours' coal-consumption trial at four-fifths of her full power, the results given above show that the *Goliath*, as regards her capabilities in this direction, can claim to hold first place among the sister battleships of her class.

As special interest is now being taken in the application of the latest improved Belleville boilers to war ships, practical tests have been made at the boiler works of John Penn & Sons, at Deptford, with two of the boilers of the *Goliath*, to determine funnel-base temperatures, coal consumption, feed water used, evaporation, etc., the results of which are herewith given in tabulated form:

Test trials of two of the boilers of H. M. S. Goliath, made by John Penn & Sons, at Deptford.

Date of trial	August 11, 1898	August 12, 1898.
Duration of trial	4 hours	4 hours.
Type of boiler	8-element Belleville boiler with economizer.	9-element Belleville boiler with economizer.
Number of boilers in use	One	One.
Total area of fire grate in use	48.5 square feet	54.6 square feet.
Total heating surface in use	1,549.5 square feet (995.2 blr., 554.3 ecr.).	1,766.3 square feet (1,119.6 blr., 646.7 ecr.).
Heating surface—grate area	31.95	32.35.
(B) Steam pressure in boilers	298.75 lbs	300 lbs.
Pressure of air in boiler-room	0.875 in. of water (vacuum at base of funnel).	0.875 in. of water (vacuum at base of funnel).
Furnace air pumps:		
Revolutions per minute	85	81.68.
Pressure of air	12.625 lbs. per sq. in	12.56 lbs. per sq. in.
Temperatures:		
Gases at base of funnel	366.25° F	523.75° F.
(A) Feed water	58° F	58.25° F.
Feed water on leaving economizer	246.31° F	255.25° F.
Coal:		
Total used per hour	1,445 lbs	1,638 lbs.
Per square foot of grate per hour	30 lbs	30 lbs.
Description	Welsh, from Penllyn, Merthyr.	Welsh, from Penllyn, Merthyr.
Approximate thickness of fires	About 5 in	About 5 in.
Interval between firing each furnace	3 minutes	3 minutes.

Test trials of two of the boilers of H. M. S. Goliath, made by John Penn & Sons, at Deptford—Continued.

Feed water:		
Total used per hour	14,273 lbs	16,779 lbs.
Per square foot of heating surface per hour	9.211 lbs	9.5 lbs.
Per pound of coal	9.877 lbs	10.243 lbs.
Equivalent evaporation to dry saturated steam:		
Per square foot of heating surface per hour—		
Based on (A) and (B)	9.211 lbs	9.5 lbs.
From and at 212° F	11.274 lbs	11.618 lbs.
Per pound of coal:		
Based on (A) and (B)	9.877 lbs	10.243 lbs.
From and at 212° F	12.089 lbs	12.527 lbs.
Evaporative power of the coal used (from and at 212° F.), and how ascertained.	14.22 lbs. (by Thompson calorimeter).	14.22 lbs. (by Thompson calorimeter).
Manner in which steam was disposed of	Escaped to atmosphere; funnel blast; air blower and feed pump.	Escaped to atmosphere; funnel blast; air blower and feed pump.
Efficiency of boiler	0.851	0.88.

GLORY.

The battleship *Glory*, of the *Canopus* type, of 12,950 tons, 13,500 I. H. P., and 18.5 knots speed (estimated), commenced her trials about the 1st of February, with a preliminary run of thirty hours at one-fifth power; but the consumption was too high, and modifications became necessary in the furnaces. The results of the repetition of this trial are not available.

At the conclusion of her thirty hours' trial at nominally 10,250 horsepower, on February 8, the contractors decided to make a few minor alterations at Portsmouth before starting on her full-power trial. At this trial (at four-fifths power) the vessel was on an even keel, drawing 26 feet fore and aft, and had 240 pounds of steam in boilers. The vacuum was 27.4 inches starboard and 26.4 inches port, and the revolutions were 99.4 and 99.2, respectively, with a total indicated horsepower of 10,587. The vacuum in smoke boxes was 0.34 inch. During the trial she made four runs over the deep-sea course with a mean speed of 16.78 knots, but on the third run the ship had to deviate from her course to avoid a sailing ship, and this materially brought down the average, which, it is estimated, would otherwise have exceeded 17 knots. The coal consumption worked out at 1.7 pounds per horsepower per hour, against 1.68 pounds in the *Canopus*. When off St. Catherine's, some hours after the close of the trial, a slide rod in the main starboard engine broke, but the mishap did not prevent the ship going ahead with the damaged engine, although she was powerless on that side for going astern; 18.78 knots was her highest mean speed on the measured mile at this trial, but the recorded mean speed was 16.78 knots—less than the actual speed—on account of the unfortunate occurrence above mentioned.

The eight hours' full-power trial took place on the 23d of February. It was decided to make this trial over the new 25-fathom course recently plotted out by the Portsmouth Reserve, and the vessel proceeded to Portland on the 22d, having previously completed her anchor trials at Spithead, and anchored there for the night.

At 5.30 a. m. on February 22 she got under way with 70 revolutions, which gave her a speed of 12.5 knots, and the speed was steadily increased to full power by the time the measured distance off the Cornish coast was reached, at 8 o'clock. Four runs were made over the 23-mile course off Start Point in the teeth of a moderate westerly gale, and her trial finished on the return run up Channel. Under the somewhat adverse circumstances a speed of 18.124 knots was obtained. Throughout the entire trial the engines and boilers worked satisfactorily. The results of the trial were as follows: Mean steam in boilers, 275 pounds; vacuum, 27 inches starboard, 26 inches port; revolutions, 108.5 starboard, 106.7 port; I. H. P., 7,021 starboard, 6,724 port; total mean I. H. P., 13,745; coal consumption, 1.58 pounds per indicated horsepower per hour. After finishing the trial, the usual stopping, starting, and reversing trials, etc., were completed.

TRIENNIAL SPEED TRIALS OF VESSELS OF THE SECOND RESERVE.

The following table shows the recent mean speeds on a three hours' run of these vessels tried at Portsmouth, as compared with their original speeds. All of the vessels given below are ironclads except the *Iris*, which is a second-class cruiser.

Name of ship.	Displacement.	Built.	Speed in knots.	
			Original.	Present.
Iron Duke	6,010	1871	13.10	9.25
Glatton	4,910	1872	12.11	9.70
Hercules	8,680	1868	13.80	13.60
Invincible	6,010	1870	13.18	11.27
Iris	3,730	1877	18.00	15.43
Nelson	7,630	1880	14.20	11.30
Neptune	9,310	1878	14.20	11.25
Sultan	9,290	1871	14.13	13.50
Swiftsure	6,910	1872	13.75	11.40

CRUISERS.

HYACINTH.

The first trial of the second-class cruiser *Hyacinth* was a thirty hours' run at a mean I. H. P. of 2,000. The trial was satisfactory. The mean results were: Steam, in boilers 197 pounds, at engines 179 pounds; vacuum, starboard 27.25 inches, port 27.31 inches; revolutions, starboard 99.6, port 101.2; I. H. P., starboard 1,102, port

1,033—total, 2,135; speed, 12.1 knots; coal consumption per I. H. P. per hour, 1.73 pounds.

Her second run was also for thirty hours at four-fifths power, and the result was again satisfactory. The mean results were: Steam, in boilers 260 pounds, at engines 229 pounds; vacuum, starboard 26.1 inches, port 26.8 inches; revolutions, starboard 150.4, port 151.7; I. H. P., starboard 3,890, port 3,828—total, 7,718; consumption of coal per I. H. P. per hour, 1.47 pounds; speed, 17.34 knots.

The program of speed trials was completed in the early part of December with a run of eight hours at full power. The engines worked smoothly throughout, the engine power developed being considerably in excess of the amount stipulated for in the conditions of contract. Unfortunately the speed was not so high as might have been expected, as the vessel could only steam at 19.4 knots with the engines working at 10,536 I. H. P., whereas when designed it was estimated that she would attain a speed of 20 knots with the engines working at 10,000 I. H. P. The mean results for the eight hours' run were: Steam, in boilers 251 pounds, at engines 241 pounds; vacuum, starboard 25 inches, port 26.9 inches; revolutions, starboard 169.15, port 173.5; I. H. P., starboard 5,269, port 5,267—total, 10,536. The coal consumption for the trial worked out at 1.58 pounds per I. H. P. per hour. Anchor and steering engine trials were then carrried out successfully.

HIGHFLYER AND MINERVA.[1]

A competitive test has been held to determine the comparative merits of Scotch and Belleville boilers. The two ships selected were the second-class cruisers *Highflyer* and *Minerva*, both having a displacement of 5,600 tons and a length of 350 feet. The *Highflyer's* engines, with natural draft, develop 10,000 I. H. P., against 9,600 of the *Minerva* with forced draft. *Highflyer* has 18 water-tube boilers of the Belleville type, fitted with economizers, while the *Minerva* has 8 boilers of the old-fashioned Scotch cylindrical type. The program of trials was as follows:

Number of trials.	Series.	Duration in hours.	Speed.
Three	A	60	10 knots.
Two	B	60	14 knots.
Two	C	60	17 knots.
Two	D	30	Highest speed that can be maintained.
Two	E	12	
Two	F	12	

The *Highflyer*, after having repairs made to her machinery, had another series of trials which terminated June 20, 1900, with a two hours' forced-draft trial. With a pressure of 295 pounds in the boilers she made 179 revolutions and 19 knots, giving 10,185 I. H. P.

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[1] For full description of these trials, see Chapter IV, Engineering Notes, Boilers.

ROSARIO.

Completed her trials with an eight hours' full-power natural-draft trial on January 25. She is the first sloop tested with water-tube boilers, and carried out the whole of her trials without a hitch. The results of this trial were as follows: Pressure of steam in boilers, 235.4 pounds; pressure of steam at engines, 185.4 pounds; revolutions, 205.3 per minute; I. H. P., high 400.5, intermediate 524.5, low 573, total 1,498. The contract provided for 1,400 horsepower, so that there was a margin of 98 to spare. The speed of the *Rosario* was exactly that estimated by her designer, viz, 13.6 knots per hour. The contract speed was 13.25 knots. The machinery of the *Rosario* was made at Devonport.

CONDOR.

The new sloop *Condor* has also satisfactorily completed the whole of her steam trials, and except for the little hitch when her piston rod became overheated, and she had to be towed back into harbor, she has gone through the ordeal most successfully, and in one or two respects with even better results than her dockyard-engined sister, the *Rosario*. The eight hours' trial of the *Condor* gave an average I. H. P. of 1,462.5, being 62.5 H. P. more than was required by the contract. This was 35.5 H. P. less than the mean of the *Rosario's* machinery; but the mean steam pressure in the boilers of the *Condor* was 231.7 pounds, compared with 235.4 pounds in the *Rosario*. The engines of the *Condor* worked 197.1 revolutions per minute, while the *Rosario's* average was 205.3. The difference in speed was infinitesimal, the *Condor* averaging 13.68 knots per hour, and the *Rosario* 13.6 knots. The *Condor* had an advantage over her sister sloop in the matter of coal consumption, her average being only 1.55 pounds per I. H. P. per hour. The *Condor* is to be finished by the end of the financial year, but, as in the case of the *Rosario*, overtime will have to be extensively resorted to in order to insure this.

GUNBOATS.

SEAGULL.

The *Seagull*, torpedo gunboat, which is the only ship in the English navy fitted with the Niclausse water-tube boiler, has concluded a series of nine trials, each of approximately 1,000 miles. Four of the runs fell short of the required distance, owing to the bad weather. At the four early trials the I. H. P. ranged from 1,354 to 1,371, and the speed varied from 13 to 13.6 knots. The next trial gave a speed of 14.48 knots, with 1,611 I. H. P., but on the following trial, with an additional 20 I. H. P. the speed went up to 14.6. The next trial was carried out in very bad weather, and had to be abandoned when only 855 miles had been run; but with 1,798 I. H. P. the average speed was 15.2 knots. The next run was in such fine weather that the ship was able to complete the thousand miles, and then, with 2 additional I. H. P., her speed improved by 2 points. At the final trial, with 1,947 I. H. P., the speed was 16.07 knots. Throughout the trials only four of the six boilers were in use, and, as the engines are capable of 3,000 I. H. P., the actual power at the time of the last trial was, for the number of boilers in use, nineteen-twentieths of the maximum. The maximum coal consumption for the entire series of trials works out at 1.9 pounds per horsepower per hour for the main engines, and 2 pounds for all purposes. The Niclausse type of boiler has been shown to possess certain advantages, the chief of which is that any tube can be quickly removed and another substituted, while all the tubes, which are 3.25 inches in diameter, are straight. When the trials were begun, the lanterne, or end of the tube, was screwed on, but now the tube and lanterne form one solid drawn piece, which materially facilitates the substitution of tubes.

SKIPJACK.

The torpedo gunboat *Skipjack*, which has had upward of £30,000 expended on her in fitting new engines and water-tube boilers, has been subjected to satisfactory trials in the English Channel. Her new engines are designed to indicate 6,000 horsepower. She averaged 20.5 knots at her speed trial.

SPEEDWELL.

The *Speedwell*, torpedo gunboat, which was re-boilered at Jarrow, had a thirty hours' coal-consumption trial in December which resulted satisfactorily. She ran twenty hours consecutively, but owing to a dense fog the trial had to be delayed two hours. The results of the trial were: Steam, in boilers 201.9 pounds, at engines 199.6 pounds; vacuum, starboard 27.9 inches, port 26.6 inches; revolutions, starboard 217.1, port 215.8; I. H. P., starboard 661, port 627, total 1,288; coal consumption per I. H. P. per hour, 1.59 pounds; air pressure, 0.36 inch; speed, 13.8 knots.

BRAMBLE.

The new first-class gunboat *Bramble* completed her trials satisfactorily. The mean results of the thirty hours' trial, held November 13–14, 1899, were: Steam, in boilers 199 pounds, at engines 191 pounds; vacuum, starboard 26 inches, port 26 inches; revolutions, starboard 235.8, port 236.9; I. H. P., starboard 336, port 325, total 661; coal consumption per I. H. P. per hour, 2.32 pounds; air pressure, 0.26 inch; speed, 10.85 knots.

The mean results of her contractors' eight-hours' natural-draft trial on November 17 were: Steam, in boilers 227 pounds, at engines 202 pounds; vacuum, starboard 22.8 inches, port 25.7 inches; revolutions, starboard 266.2, port 263.1; I. H. P., starboard 495, port 445, total 940; air pressure, 0.45 inch; speed, 11.11 knots.

The results of her final eight hours' trial, held on November 18, were: Steam, in boilers 211 pounds, at engines 190 pounds; vacuum, starboard 25 inches, port 25.4 inches; revolutions, starboard 300.6, port 305; I. H. P., starboard 674, port 686, total 1,360; air pressure, 1.15 inches; speed, 13.38 knots.

BRITOMART.

Bramble and *Britomart* are gunboats of 710 tons, intended for river service. The latter, in her first thirty hours' trial off Plymouth, maintained a speed of 11.2 knots with an I. H. P. of 667. The mean results were: Air pressure, 0.24 inch; steam in boilers, 220 pounds; steam at engines, starboard 207 pounds, port 208 pounds; vacuum, starboard 26 inches, port 25.4 inches; revolutions, starboard 241.3, port 238.1; I. H. P., starboard 344, port 323, total 667.

On the eight hours' steam trial, January 22, 1900, at 900 I. H. P. (four-fifths power), the mean results were: Steam, in boilers 208 pounds, at engines, starboard 188, port 196 pounds; revolutions, starboard 274.8, port 276.4; vacuum, starboard 26.8 inches, port 25 inches; I. H. P., starboard 476, port 481, total 957; air pressure, 0.5 inch; coal consumption per I. H. P. per hour, 2.52 pounds; speed, 13 knots.

She had a four hours' forced-draft trial on January 25, with the following results: Steam, in boilers 224 pounds, at engines 198 pounds; air pressure, 1.2 inches; vacuum, starboard 25.1, inches port 24.6 inches; revolutions, starboard 309.6, port 313.3; I. H. P., starboard 661, port 708, total 1,369; speed, 14.6 knots. Contract required 1,300 I. H. P., 13.5 knots.

TORPEDO-BOAT DESTROYERS.

ALBATROSS.

The official results show that the three hours' coal-consumption trials of the *Albatross*, which took place on March 26, 1900, were of a satisfactory character. A speed of 31.5 knots had to be obtained, and this was slightly exceeded. The engines registered 7,784 I. H. P., with 379.9 revolutions per minute, and a steam pressure in the boilers of 240 pounds per square inch.

ELECTRA.

The *Electra* successfully passed her official trials at Portsmouth in January.

KESTREL.

Results of a ten hours' coal-consumption trial of the *Kestrel* October 27, not heretofore noted, worked out as follows: Speed, 13 knots, with 475 I. H. P.; coal consumption, 2.24 pounds.

OTTER.

The *Otter* completed her trials in October, at Devonport, with satisfactory results.

OSPREY.

Osprey made 28.2 knots off Plymouth in a heavy sea, all weights on board. "This is a very fine performance," says the *Engineer*, "and rather takes away from the French creed that our destroyers can not exceed 25 knots or less in a seaway." The *Osprey* is a 340-ton, 30-knot, Fairfield boat.

PETREL.

The tenth 30-knot torpedo-boat destroyer built and engined by Palmers underwent her three hours' coal-consumption trial from Portsmouth dockyard March 30, 1900. An average of six runs over the measured mile gave a speed of 30.322 knots, with 384.6 revolutions and 240 pounds steam pressure, the I. H. P. being 6,632 and vacuum 27 inches. For the three hours the speed aimed at was 30.1 knots, the intention being only to exceed the 30 knots guaranteed. The results were: Speed, 30.097 knots, 380.6 revolutions, 239 pounds of steam, 6,438 I. H. P., and 27 inches of vacuum. The trial was run on a heavier displacement than any of Palmers' previous 30-knot boats, and this enhances materially the value of the performance. The highest speed reported was 32.59 knots with 378.9 revolutions. Coal consumption, 2.3 pounds per I. H. P. per hour.

SPITEFUL.

The first trial was stipulated to be at a speed of about 29.75 to 30 knots for three hours, to test the coal consumption, which was not to exceed 2.5 pounds. It was found that at 29.9 knots the consumption was at the low rate of 2.3 pounds.

On the second trial the vessel was to be driven at not less than 30 knots during three consecutive hours, but at the same time it was desired to keep the speed as little in excess of 30 knots as possible. On six runs over the mile the speed was easily maintained at 30.371 knots, and the engines were then adjusted so that the average of the three hours came out 30.06 knots.

On the final, or twelve hours' trial, the vessel was to be run at a speed of 13 knots and the consumption measured. The average speed was 13.05 knots, the power 450 I. H. P., and the consumption is officially given as being at the rate of 1.5 pounds per I. H. P. per hour, so that the coal (about 116 tons) she is capable of stowing would at this rate enable the vessel to steam about 4,000 nautical miles. She is generally similar to the other 30-knot boats built by Palmers, and has two sets of triple-expansion engines and four of Read's water-tube boilers, working at 250 pounds and 6,300 I. H. P.

VIPER.

The torpedo-boat destroyer built to the order of the Admiralty by the Parsons Marine Steam Turbine Company, Limited, Wallsend-on-Tyne, made a preliminary trial in November in a rough sea, attaining 32 knots with three-quarters of her power, 10,000 I. H. P.

In her second preliminary trial, on January 9, 1900, a mean speed of 34.8 knots was obtained in four consecutive runs on the measured mile, the fastest run being at the rate of 35.5 knots. The speed attained was considerably in excess of that required by the contract, namely, 31 knots.

The *Viper* is 210 feet long, 21 feet beam, 12.5 feet deep, and of 325 tons displacement. Yet in her engine room, 28 feet by 21 feet, there are placed six turbines, four of which are capable of exerting 12,000 I. H. P., the other two being used only for going astern. At the time of attaining the highest speed on record the *Viper's* motors were using steam equivalent to 11,000 I. H. P. The motors are arranged to drive four shafts, each carrying two screw propellers, or eight in all, running at about 1,800 revolutions per minute, and the turbine engines are so arranged that the vessel may go backward at a rate of 15 knots with four screws working. Notwithstanding the enormous power, there is ample space in the engine room. When doing her highest speed the vessel was as free from vibration as a sailing ship, and a gunner could have laid a gun with just as great ease as if he had been on a first-class battleship. It is understood that as a result of the showing made on this trial Mr. Parsons, the designer, has decided to decrease the diameter of the screws and vary the pitch. He believes that by so doing it will be possible to secure additional speed.

The official trial of the *Viper* was made on the North Sea, off the mouth of the Tyne, on the 4th of May. The displacement on trial was 370 tons, with all coal on board. The contract load was 40 tons, but, as a matter of fact, the vessel had on board 60 tons. The vessel turned north and ran as far as the measured mile with the wind and sea quarterly. Full steam had not been reached when she entered on the mile, and even on the second run the speed did not quite reach 30 knots. Ten runs were made in all, and taking the best six consecutive runs—with and against tide—a speed of 34.28 knots was reached. The best two runs gave a mean speed of 34.75 knots, while the mean speed on a three-hours' run was 33.96 knots.

The mean revolutions were 1,050 per minute, and the mean steam pressure was 165 pounds to the square inch, the maximum being 175 pounds. In regard to this point it should be stated that a great deal of steam was lost at the relief valves, which had not been sufficiently screwed down before starting and began to blow heavily soon after going on the mile. The total heating surface in the four Yarrow boilers is 15,000 square feet, and the grate surface is 275.75 square feet. The air pressure for draft averaged 3 inches on the water gauge. The I. H. P. estimated by the steam pressure and revolutions is taken at 11,000. The trial was carried out under Admiralty conditions strictly.

ZEBRA.

The *Zebra* on November 9, 1899, attained a speed of 27 knots with 4,500 I. H. P.

SUBMARINE BOATS.

(See under trials of submarine boats in France, page 49).

FRANCE.

BATTLESHIPS.

CHARLEMAGNE, GAULOIS, ST. LOUIS.

These new battleships of 11,275 tons displacement, 14,500 estimated horsepower, and 18 knots speed, all having Belleville boilers, have been undergoing their trials during the last few months, a few details of which are available.

The trials consist of the following: At 9,000, at 5,000, and at 11,000 I. H. P., with natural draft; at about 15,000 I. H. P., maximum power; a trial of twenty-four hours at 9,000 I. H. P.; a trial with mixed fuel, coal and petroleum; and trials of guns, torpedoes, and anchors.

The boilers of the *Charlemagne* and *Gaulois*, which steamed for four days at a continuous speed of 15 knots, were, according to the *Echo de Paris*, in such a condition at the end of that time that engineers were a fortnight in effecting repairs.

The following are comparative details of the trials of the *Charlemagne* and *Gaulois*, twenty-four hours' run at two-thirds speed:

Gaulois.—I. H. P., 9,200; corresponding speed, 16.5 knots; coal consumption, 1.53 pounds per I. H. P. per hour.

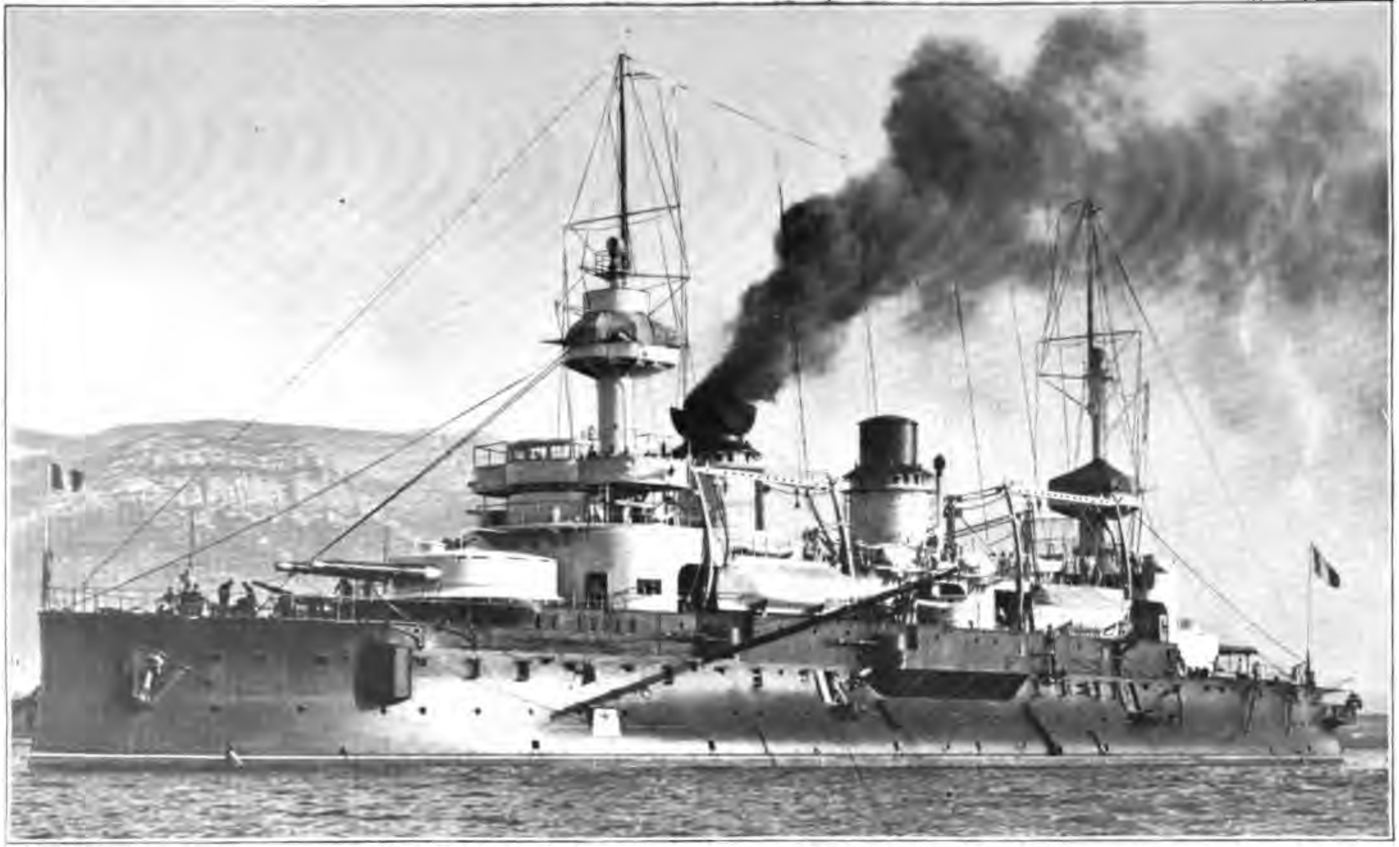
Charlemagne.—I. H. P., 9,270; corresponding speed, 16.41 knots; coal consumption, 1.55 pounds per I. H. P. per hour.

The results of the three hours' run at full speed under forced draft were as follows:

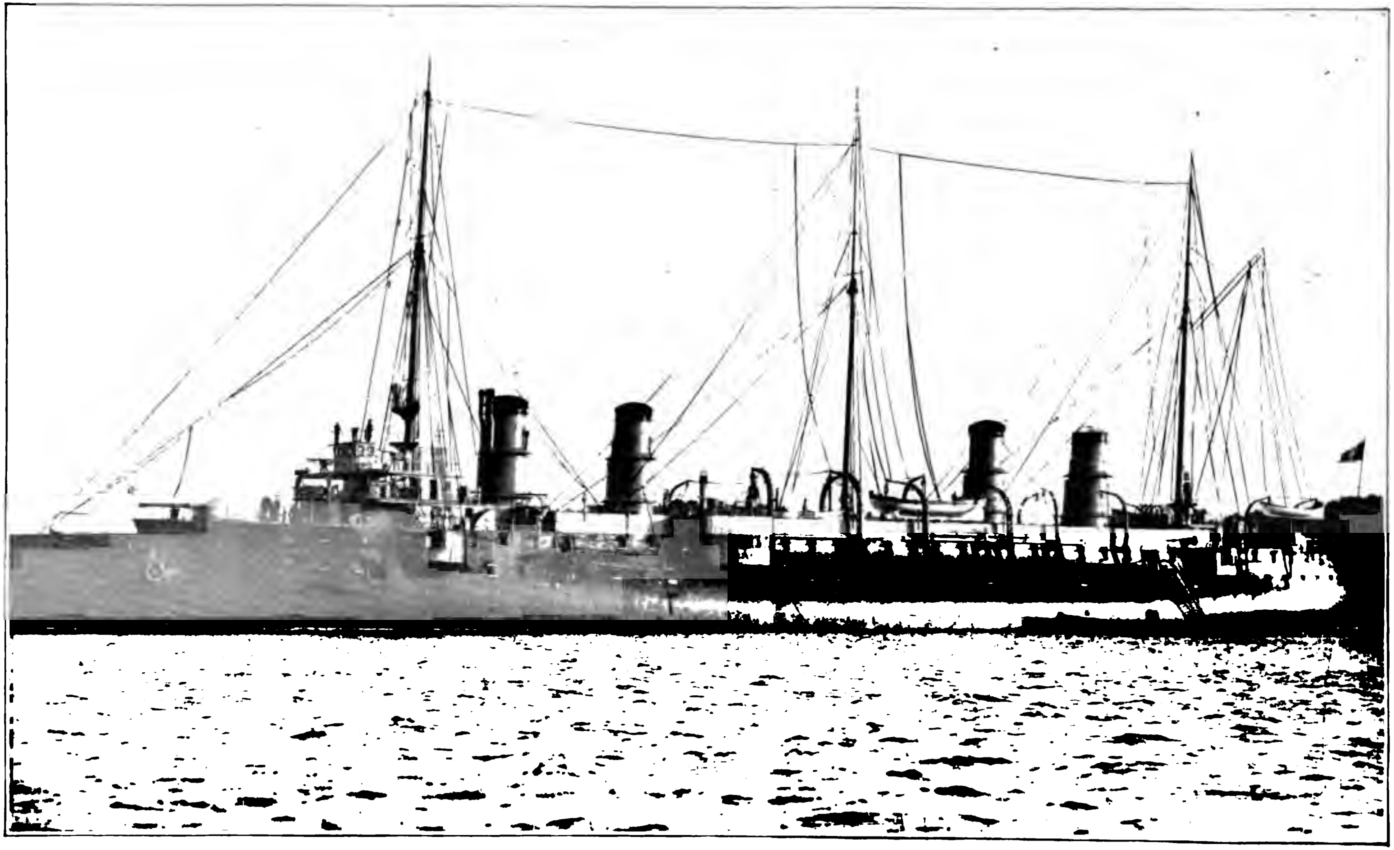
Gaulois.—I. H. P., 14,925; corresponding speed, 18.02 knots; coal consumption, 1.78 pounds per I. H. P. per hour.

Charlemagne.—I. H. P., 15,295; corresponding speed, 18.136 knots; coal consumption, 1.92 pounds per I. H. P. per hour.

The preliminary trials of the *St. Louis*, made in March, 1900, are said to have been satisfactory, the run off Brest with 14,000 I. H. P. having resulted in a speed of 17.61 knots. She is expected on her final trials to reach the speed of 18 knots.



GAULOIS. (France, first-class battleship) 11,275 tons, I. H. P., 14,500; speed, 18 knots; launched, 1896.



GUICHEN. (France, protected cruiser) 8,277 tons I H. P., 24,000; speed, 23 knots; launched, 1897.

CRUISERS.

GUICHEN.

After extensive alterations had been made in the propellers of the *Guichen* she made full-speed trials on the measured mile off the Hyères Islands on the 9th of November last, full details of which are as follow:

Duration of trial		3 hours.	
Mean pressure on the boilers		187.26 pounds.	
Air pressure in stoke hole		0.988 inch.	
Temperature in engine rooms		95° to 126.5°.	
Revolutions per minute of engines	Starboard	135.2	Mean, 136.38.
	Center	136.8	
	Port	137.15	
Mean I. H. P.		25,455.	
Number of runs over mile		2.	
Mean speed of the two runs		23,544 knots.	
Consumption of coal per H. P. per hour		1.75 pounds.	
Consumption of coal per square foot of grate and per hour		26.586 pounds.	
Mean vacuum, in mercurial centimeters		65.5.	

During the whole trial the working of the machinery was perfect, the stoking easy, and the engines worked silently and with remarkable regularity. There was no perceptible vibration out of the ordinary in the ship, and she steered easily. The conditions required by the contract were: A three hours' trial at 25,000 I. H. P., and 23 knots speed, with a consumption of coal per square foot and per hour not exceeding 32.78 pounds.

The ship was constructed by the Société de la Loire at St. Nazaire, on the plans of M. Bussy, and engines at the works of the same company at St. Denis, on the plans of M. Boulogne. The result obtained $\left(M=3.68 \text{ in the formula } V=M\sqrt[3]{\frac{F}{B^2}}\right)$ shows that the lines of the hull are peculiarly well adapted to insure a high rate of speed, and this is confirmed by the fact that there was little or no appreciable bow or stern wave. If, besides, it be considered that on the measured distance used for the trial the water has but a mean depth of 124.6 feet, it may be assumed that in deep water the speed obtained would have been somewhat increased.

On February 10, 1900, the *Guichen* made a trial at full power with but two screws working, the central screw not running, a case which might present itself in case of accident, for example. This trial was made for the information of the navy. The *Guichen* has been given a third mast, placed between the two forward and the two after funnels, on which there is installed a Temperley transporter for coaling at sea.

CHATEAURENAULT.

March 17, 1900, the *Chateaurenault*, which closely resembles the *Guichen* (differing chiefly in the manner in which the motive apparatus is placed, the central engine being abaft the two outer engines, instead of between them, as upon the *Guichen*, and the boilers—of the Normand-Sigaudy type instead of d'Allest, as upon the *Guichen*—being all forward of the engines), made a second preliminary run, during which it held speed trials with natural draft. The ship was enabled to reach the speed of 22.7 knots with somewhat over 19,000 I. H. P.; and during the whole run the working of the boilers (which have never heretofore been employed on vessels of greater power than the torpedo destroyers *Dunois* and *Lahire*), as well as that of the rest of the machinery, has left nothing to be desired.

A local Toulon paper reports that the *Chateaurenault* has completed her preliminary builders' trial, and that with a development of 21,800 I. H. P. she made a speed of 23.2 knots. As this vessel, like the *Guichen*, was designed for a horsepower of 23,000, it is believed that she will reach a speed of 24 knots an hour.

The lines of the *Chateaurenault* are somewhat finer than those of the *Guichen*, and the disposition of the screws is markedly different. In the *Guichen* the three screws are very nearly in the same plane, while in the *Chateaurenault* the side screws are about 29.52 feet forward of the center screw.

DU CHAYLA.

The second-class cruiser *Du Chayla* has lately completed a twenty-four hours' trial at full speed, during which she averaged 18.5 knots. She is supposed to be a 20-knot ship, and doubtless might reach that speed on a spurt under favorable conditions of weather.

Gunboats and Torpedo Boats.

ZÉLÉE.

The gunboat *Zélée* recently completed at Lorient her official acceptance trials; the boilers, of Niclausse type, giving the following results:

Date of trial.	Duration of trial.	Power used.	I. H. P.	Coal per horsepower hour.
	Hours.			*Pounds.*
June 16, 1900	6	One-third...	335	1.265
June 19, 1900	6	Full power.	953	1.590
June 22, 1900	24	500 I. H. P...	575	1.603

These very remarkable results in coal consumption were obtained with boilers of torpedo-boat type, having tubes of 1.575 inches, the same as were used in the *Téméraire*.

The rapidity with which the trials were made shows that the boilers and engines worked very satisfactorily.

ARGUS AND VIGILANTE.

The trials of the shallow-draught gunboats *Argus* and *Vigilante*, built by Messrs. John I. Thornycroft & Co., of Chiswick, to the order of the French Government, have been successfully completed. The *Vigilante* made her first run down the Thames April 9, and on an official trial of two hours' duration, with full load on board, attained a mean speed of 13.25 knots. The *Argus* satisfactorily completed her official trial on April 6, when she attained a mean speed of 13.4 knots on a two hours' run.

These vessels are practically sisters of the English gunboats *Woodcock* and *Woodlark*, built by the same firm, and are destined for similar locations—service on Chinese rivers. They are similarly armed and have the same hard steel plate protection to their vitals; this protective plating is less than an eighth of an inch thick. The French gunboats have about three-quarters of a knot more speed, owing to improvements in the machinery. They are to be accompanied by four large store barges, and all six of these craft are built in sections. They are of 300 tons displacement.

LAHIRE.

The new destroyer, *Lahire*, of 896 tons displacement, having had her screws changed, resumed her trials at Cherbourg, but even now has fallen short of the contract speed by nearly a knot; with 4,200 I. H. P. she attained a speed of 20.4 knots, and with 7,100 I. H. P. a speed of 22.1 knots; the contract speed was to be 23 knots with 7,000 I. H. P.

FRAMÉE.

Contract speed, 26 knots. On a run between Lorient and Belle-Ile she maintained a mean speed of 24 knots with natural draft; with forced draft a speed of 27.5 knots was reached on the measured base. After a change in her screws she made further runs in March, with very successful results, giving a speed varying from 26 to 28 knots during two hours, with favorable weather. The mean speed was 26.91 knots. The vessel is to be attached to the Mediterranean squadron.

FIRST-CLASS TORPEDO BOATS NOS. 229, 212, 213, 236, 237, 238.

The torpedo boat No. 229, of 90.1 tons displacement, made 25.5 knots mean speed on her trials.

Two boats, Nos. 212 and 213, delivered in December, 1899, the results of trials are as follows:

	No. 212.	No. 213.
Displacement on trial, in English tons	86.1	86.1
I. H. P. at 14 knots	302	302
Consumption of coal per hour (mean of eight hours) ... pounds	305	292
Full speed (mean of two hours' run) ... knots	26.81	26.87
I. H. P.	1,955	1,900
Consumption of coal per hour ... pounds	3,000	3,040
Consumption of coal per I. H. P. at 14 knots ... do	1.015	.967
Consumption of coal per I. H. P. at full speed ... do	1.535	1.600

The two hours' trials were preceded by three runs and followed by three other runs on the measured mile, no alteration being allowed in the valves, introduction, etc., during the whole trial. The boats were fully equipped for sea, including 20.5 English tons for torpedoes, launching tubes, and compression pumps, artillery and ammunition, reserve water, coal, men and equipment, water, and stores. The coal carried was not to be less than 10.3 tons, which, according to the consumption trials, corresponds to 1,060 nautical miles at 14 knots for No. 212 and to 1,110 for No. 213.

Torpedo boats 236, 237 and 238 in their trials at Lorient exceeded the speed of 25 knots required.

The six torpedo vedette boats D, E, F, G, H, and I, recently delivered at the port of Toulon, also exceeded the speed of 18 knots expected of them.

SUBMARINE BOATS.

The *Morse* held an official trial on March 9, on which occasion it attained the speed of 12.32 knots.

Trials of the submarine, or rather submersible *Narval*, were carried out at Cherbourg in December. Some difficulties developed which it is hoped will be overcome, and which explain the delay in the construction of the *Sirène* and *Triton*, of the same type. The difficulties are reported not to be due, as has been said, to the length of time taken in changing from one form of motive power to another just before making a dive, for this is a very simple operation; they lie rather in the dive itself. The spindle-shaped outer hull, resembling that of an ordinary torpedo, which sustains the pressure of the water at great depths, is light, and it will doubtless be necessary to secure a more complete subdivision of this space in order to regulate methodically the introduction of water to insure stability.

A commission was appointed by the French Prefect of Marine in the autumn of 1899 for the purpose of carrying out experiments with the submarine navigation of the new type of boat constructed by Goubet, the *Goubet No. II.* This boat is almost spherical in shape, is about 3 meters in depth, 3 meters beam, and 4 meters in length. It is propelled by a screw with a diameter of 80 centimeters, and two fins or rudders are placed port and starboard for manœuvring the boat when it is submerged.

A series of trials, preliminary and official, were carried on by this boat during December, during the course of which she remained submerged at the depth of 5 meters for a period of five hours. Then she crossed the roadstead at Toulon, making two dives, each for a distance of from 50 to 60 meters, in the middle of the passage. When the *Goubet* disappeared, a steam launch accompanying it manœuvred to find it for twenty minutes, but was unsuccessful, although the optical tube of the submarine was above water all the time and the persons submerged in the boat could see the persons on the launch all the time. The return to the moorings of the *Goubet* was effected in a straight line and at a speed of 6 knots, as estimated from the number of revolutions made by the screw of the accompanying steam launch. This is a knot in excess of the required speed of the submarine boat.

Another preliminary run is remarkable because of the bad easterly weather prevailing in the roadstead, which also the same day, December 18, prevented the torpedo boats from getting under way. While moving at the surface the dome was constantly covered by the waves, but the stability of the boat was perfect. The flagstaff was not seen to oscillate. After passing the wharves, the boat was seen to dive for a length of 200 meters, and then to go direct to Tamaris without being troubled by the swell and waves which it received on the broadside at the opening of the broad channel.

Ten days later, making use of the long mole as a measured base (length 1,212 meters), and still having bad weather, speed trials were run, the motors alternating from mean to maximum speed. The mean of the runs was eight minutes, corresponding to the expected speed of 5 knots. This speed was obtained with the boat displacing 10 tons and having at its disposal less than 5 horsepower of electro-motive power. Upon the return of the boat, it effected a plunge for about 80 meters' distance near the warships, made a turn astern of them but a few meters distant, then suddenly disappeared and remained invisible several minutes at a depth of 7 meters before resuming its course toward the arsenal.

In England, although certain engineering papers and some naval authorities take a decided view of the uselessness of the French submarine boats, and openly express the opinion that in actual war they will be found altogether unserviceable, the Admiralty are giving some attention to the question of submarine boats.

GERMANY.

According to a new determination on the part of the German navy department, the works intrusted with the building of a ship are to have charge of her trials up to the time when she goes into commission. Formerly the Government works at Kiel and the trial commission which had its sittings at Kiel had charge of all trials.

Seven new warships will be able to make their trials during the year 1900, the battleships *Kaiser Wilhelm II* and *Kaiser Wilhelm der Grosse*, the large cruiser *Fürst Bismarck*, the small cruisers *Niobe* and *Nymphe*, and the gunboats *Tiger* and *Luchs*, not to mention quite a number of large torpedo boats which are built as torpedo-boat destroyers. As the work on the interior of all these ships is being industriously advanced, all seven ships will probably be assigned to active service in the fleet during the year.

BATTLESHIPS.

During the early part of March the *Kaiser Wilhelm II* had a satisfactory twenty-four hours' acceptance trial. As the engines were not run up to their maximum power, the speed was not measured. With forced draft another trial was made, when a speed of 18 knots an hour was obtained.

CRUISERS.

The large cruiser *Vineta* successfully made her coal-consumption trials in November, and with forced draft attained a speed of 19 knots. Both hull and engines met all requirements and stood the tests excellently. During the trial 11,000 I. H. P. were developed, and a speed of 20 knots per hour was attained during a five-days' speed trial on the open sea.

The large cruiser *Fürst Bismarck* has been running trial trips during the spring, the results of which have been satisfactory. During one of these, held April 26, it is reported that with 60 revolutions the engines developed 2,600 I. H. P., and when the revolutions had been gradually worked up to 80 the I. H. P. reached 5,000. Engines and boilers worked without any difficulty.

On April 29, the *Fürst Bismarck* made her second twenty-four hours' trial. For eight hours, with 84 revolutions, she developed 6,000 I. H. P.; at night 5,000 I. H. P. was obtained with 80 revolutions, and the following morning the maximum I. H. P., 9,100, was reached with 98 revolutions. Boilers and engines worked well, and valves functioned satisfactorily.

On the morning of the 8th of May the boilers were cleaned and a four-hours' run made, followed in the course of the forenoon by a run over the mile to standardize the screws, with the following results:

Revolutions—Port, 101.6; I. H. P., 3,438. Center, 103.8; I. H. P., 3,530. Starboard, 100.0; I. H. P., 3,408. Thus giving a total I. H. P. of 10,376, the mean revolutions being 101.8, or 5.76 per minute per mile. The mean speed was 17.85 knots.

In the afternoon, the boilers having again been cleaned, two runs over the mile were made with maximum power, giving the following results:

Revolutions—Port, 107.25; I. H. P., 3,973. Center, 108.50; I. H. P., 4,261. Starboard, 105.70; I. H. P., 4,060. Total I. H. P., 12,294; mean revolutions, 107.15, or 5.8 per minute per mile. The mean speed obtained was 18.45 knots.

In all the ship ran about two hours under forced draft. The maximum power obtained was 13,021 I. H. P., with 109 revolutions per minute.

Satisfactory trial trips were also made with the battleship *Wurtemberg*, fitted with water-tube boilers on the Schulz system, in January, and a six-hours' trial with forced draft with the gunboat *Tiger*, on April 18.

Torpedo Boats.

Acceptance trials of torpedo boat S-90, held in November, 1899, gave the following results: Fourteen hours at 12 knots, coal consumption 857.59 pounds per hour (881.84 pounds being the contract limit); twelve hours at 14 knots, 1,285.28 pounds coal per hour (1,322.76 pounds the contract limit); three hours at forced speed, boat fully equipped and carrying about 65 tons of coal; average revolutions, 354 per minute; speed, 26.4 knots (terms of contract requiring 26 knots). Engine and steering trials also satisfactory.

RUSSIA.

Battleships.

PERESVIET.

The trial of the engines of the first-class battleship *Peresviet* gave as the result of eight series of diagrams the following: Highest pressure cylinder, 1,405.15 H. P.; medium, 1,527.37 H. P.; lowest, 1,633.69 H. P.; total, 4,566.21 H. P., or for the three engines, with an average pressure of steam to the square inch of 169.5 pounds, a result of 14,532 H. P., or some 32 more than the contract.

She and her sister ships, the *Osliabia* and *Pobieda*, are considered in Russia a happy combination of battleship and cruiser, having the protection of vital parts and armament, the numerous guns and solidity of the one, with the speed, range of action, and seaworthiness of the other. She has three distinct engines, each with a separate screw, her 6-inch guns are each in a casemate with 2 to 5 inches of armor, and electricity is used to a hitherto unknown extent, and her six dynamos give 6,000 ampères at 100 volts. Her engines are well protected by an armored deck, and have very small hatches.

SEVASTOPOL.

An official trial of the engines of the first-class battleship *Sevastopol*, 10,200 tons, in the presence of a commission presided over by Rear-Admiral Amosov, at full power and lasting six hours, was carried out on the measured mile at Kronstadt. The results were very satisfactory. The estimate was that both engines on an average should develop 10,600 I. H. P., at 95 revolutions of each screw and 150 pounds pressure of steam. The expenditure of coal was 2 pounds per hour per I. H. P.

Miscellaneous.

VARYAK.

The protected cruiser *Varyak*, 6,500 tons, 20,000 I. H. P., 23 knots speed, built by Cramps, made, May 30, 1900, a trial run of twenty-four hours under natural draft, and made 21 knots with 150 revolutions, reaching 22 knots at times.

The Niclausse boilers worked satisfactorily. Her official trials are to take place in July.

GILIAK.

The gunboat *Giliak*, 960 tons, at its last trial, in December, developed 1,180 I. H. P. (in place of the estimated 1,000), 215 revolutions, and a speed of 12.5 knots (in place of 12 knots contracted for).

BAIKAL.

The new ice breaker *Baikal* on the Baikal Sea, in January, developed a speed of 8 miles an hour through ice of a thickness of 14.17 inches (36 centimeters). The mean speed amounted to 5.3 miles an hour, the ice was easily broken, the engines worked smoothly, the screws functioned well in spite of the ice, and the ship's hull received no injury.

SOM.

The destroyer *Som*, built and engined by Messrs. Laird Brothers, Birkenhead, completed in March a series of very satisfactory trials on the Clyde. The contract speed with the bunkers full and all outfit and stores on board was 27 knots, and the result on her official full-speed trial (February 24) gave a speed of nearly 28 knots as a mean of six runs on the measured mile, being nearly a knot in excess of the contract speed. The results on each of the six runs were as follows:

Miles.	Steam.	Time.	Speed.
		h. m.	*Knots.*
1	225	2 11.2	27.44
2	223	2 10.4	27.61
3	223	2 7.0	28.35
4	219	2 8.8	27.95
5	215	2 9.8	27.73
6	210	2 12.0	27.27

The speed for the three hours' continuous steaming was 27.2 knots. The conditions under which this trial was run were unfavorable, owing to a heavy sea and strong southwest breeze. On February 28 and March 2, a series of progressive trials at varying speeds were carried out, as well as steering, stopping, starting, and coal consumption trials, all of which were successfully completed.

NO. 114.

The trials of torpedo boat No. 114, built on the *Anakria* type, gave a mean speed of 16 knots, with an expenditure of naphtha of 15 cwt., or about 2.3 pounds per I. H. P. per hour. There was complete combustion, almost unaccompanied by smoke. It is hoped by Engineer-

Mechanic Shchensnovich that he will obtain equally good results with water-tube boilers and artificial pulverization on board torpedo boat No. 129, built at the Ijora Works, on the type of the *Pernov*.

HOLLAND.

TORPEDO BOATS.

HYDRA AND SCYLLA.

The official trial of the *Hydra* took place on May 25, 1900, under the direction of Mr. Loder, Chief Constructor of the Royal Dutch Navy; Mr. Koning, Engineer-in-Chief, and Captain de Booy, who will command the vessel.

A mean speed of 24.37 knots was made for the three hours, with 160 pounds of steam, and a trifle over 400 revolutions per minute, the load carried being 17½ tons.

The official trial of the *Scylla* took place on June 26, with practically the same results.

JAPAN.

BATTLESHIPS.

ASAHI.

The trials of the *Asahi* began on March 20 on the measured mile in Stokes Bay, with the following results: 613 I. H. P., 6.69 knots; 1,610 I. H. P., 9.28 knots, and 4,355 I. H. P., 13.06 knots. The next day she completed her high-speed consumption trial, the result showing that at 12,947 I. H. P. the consumption was only 1.59 pounds per horsepower per hour. There was a high wind and a heavy sea, but the records taken gave an approximate speed of 17.5 knots. The ship then put in at Plymouth to clean boilers, and on March 23 started on her full-power trial between Start Point and Barry Head, a distance of 12.26 nautical miles. Four runs were made, the first and third being in the teeth of a northeasterly gale, but with this disadvantage the mean speed was 18.3 knots. The speeds on the four runs were: First run, 17.92 knots; second run, 18.08 knots; third run, 18.65 knots; fourth run, 18.3 knots. The mean I. H. P. for the entire series of runs was slightly over 16,000. After the full-speed trial circles were made to port and starboard with each steam-steering engine with the vessel still at full speed, and at a speed of 15 knots the hand-steering gear was successfully tried. On the return to Spithead, at 17 knots, the stopping, starting, and reversing trials were carried on.

FUSO.

The battleship *Fuso*, after being thoroughly overhauled at the Kure dockyard, had her trials on April 8, with the following results:

State of wind and sea	Very calm and smooth.
Amount of coal carried	350 tons.

Draught forward	17 feet 6 inches.
Draught aft	18 feet 3 inches.
Conditions of trial	Four runs over a course of 3.936 measured miles.
Steam pressure	51 pounds per square inch.
Revolutions	80.
Vacuum	26.77 inches.
Speed in knots	11.6.
Coal consumption per I. H. P	2.79 pounds.
Mean I. H. P	2,162.

Cruisers, Dispatch Vessels, etc

MIYAKO.

A trial of the *Miyako*, dispatch vessel of 1,800 tons, built at Kure dockyard, has resulted as follows: Steam pressure, 112.5 pounds; vacuum, starboard 26.2 inches, port 26.3 inches; revolutions, starboard 143.6, port 144.1; I. H. P., 3,227.2; speed, 18.02 knots. Conditions, smooth sea, light to gentle breeze. This data is the average for the six hours' full speed natural-draft trial.

AKASHI.

The third-class cruiser *Akashi* underwent trials on March 7, with results as follows:

Place of trial	Tokyo Bay.
State of wind and sea	Very calm and smooth.
Amount of coal carried	600 tons.
Draught forward	14 feet 7 inches.
Draught aft	18 feet.
Conditions of trial	Two runs over a course of 3 measured miles.
Steam pressure	135 pounds per square inch.
Revolutions	151.
Vacuum	18.5 inches.
Speed in knots	19.53.
Coal consumption per I. H. P	1.25 pounds.
Mean I. H. P	7,396.

OSHIMA.

The following results were obtained on the trials of the gunboat *Oshima*, after being overhauled at the Sasebo dockyard:

Place of trial	Sasebo.
Date of trial	December 28, 1899.
State of wind and sea	Moderately calm and smooth.
Amount of coal carried	140 tons.
Draught forward	8 feet.
Draught aft	10 feet 6 inches.
Conditions of trial	Two runs over a measured mile.
Steam pressure	147 pounds per square inch.
Revolutions	203.

Vacuum	24.41 inches.
Speed in knots	13.10.
Coal consumption per I. H. P	5.15 pounds.
Mean I. H. P	803.

TORPEDO GUNBOATS.

CHIHAYA.

This vessel, which was entirely built and engined at the Yokosuka dockyard, was successfully launched on May 26, 1900, in the presence of the Emperor and numerous other distinguished guests. Although by no means the largest vessel launched from the same yard, there has probably been more Japanese and less imported work put into her than any of her predecessors.

She is a steel boat, of 1,250 tons displacement, with triple-expansion engines of 6,000 horsepower, and her armament will consist of two 12-centimeter Armstrong quick firers, four 12-pounder Armstrong quick firers, and five torpedo tubes.

TORPEDO BOATS.

NOS. 81 TO 88.

The following are the results of the official trial of one of these boats (built by Schichau and put together in Japan): The trial took place at Sasebo July 12, with smooth sea, light airs. Steam pressure, 235 pounds; vacuum, 23.8 inches; revolutions, 392.9; I. H. P., 1,382.6; speed, 24.66 knots; coal consumption, 2.5 pounds per I. H. P. per hour. Draught, 5 feet 9 inches forward and aft. This data is the average of six consecutive runs over the measured mile. The other seven torpedo boats of this lot have all had their official steam trials with practically the same results as the foregoing, some making slightly less and others slightly greater speed. These are second-class torpedo boats, of 80 tons displacement.

NIJI.

On December 16, the destroyer *Niji* was launched, with steam up, from the yard of Yarrow & Co., Limited, in the presence of a large number of the Japanese naval authorities. On December 18, a preliminary trial was made, when a speed of 31.206 knots was obtained. The official trial took place on December 21, so that there was a gap of only five days between the launching and the official trial. The air pressure during the three hours' run varied from three-fourths inch to seven-eighths inch, and the consumption of coal for the three hours worked out at 1.98 pounds per I. H. P. per hour. The consumption per square foot of grate was 52.3 pounds. The draught of water to bottom of propellers was 7 feet 10 inches aft, 4 feet 11 inches forward. Load carried, 35 tons. Mean steam in boilers, 204.5 pounds; mean revolutions, 387.4; maximum speed (on sixth and last run), 33.707

knots; Admiralty mean, 31.106 knots. Means for three hours' trial, 204 pounds steam, 53 pounds in first receiver, 7 pounds in second receiver; 23.75 inches vacuum; mean revolutions per minute, 388.06; mean speed during three hours, 31.156 knots. After the speed trial was completed tests were made of the way the engines handled, also of the steering both by steam and by hand, all of which were to the satisfaction of the Japanese authorities.

The *Usugumo*, the sixth vessel built and engined by Thornycroft for the Japanese Government, had a satisfactory full-speed trial at the Maplin Sands on the 23d of January, 1900. The speed realized when carrying a load of 35 tons was 30.602 knots on the measured mile, and 30.370 knots on a run of three hours' duration.

Results obtained on the steam trials of torpedo boats:

HAYABUSA.

Place of trial	Atada-jima, Japan.
Date of trial	April 4, 1900.
State of wind and sea	Very calm and smooth.
Amount of coal carried	25.5 tons.
Draught forward	4 feet 6 inches.
Draught aft	4 feet 10.5 inches.
Conditions of trial	Six runs over a measured mile.
Steam pressure	196 pounds per square inch.
Revolutions	317.
Vacuum	25.98 inches.
Speed in knots	29.02.
Coal consumption per I. H. P	2.29 pounds.
Mean I. H. P	3,492

TORPEDO BOATS NOS. 29 AND 30.

Place of trial	Kure.
Date of trial	March 22, 1900.
State of wind and sea	Very calm and smooth.
Amount of coal carried	15 tons.
Draught forward	3 feet 11 inches.
Draught aft	4 feet 1 inch.
Conditions of trial	Six runs over a measured mile.
Steam pressure	220 pounds per square inch.
Revolutions	337.
Vacuum	27.56 inches.
Speed in knots	25.08.
Coal consumption per I. H. P	2.58 pounds.
Mean I. H. P	1,523.

ITALY.

PUGLIA.

The protected cruiser *Puglia*, of 2,550 tons, 7,000 I. H. P., and 19 knots speed (required), had her first official trials with natural draft off Tarente. With 4,400 I. H. P. the speed obtained was 16.2 knots. the working of the motive apparatus being very satisfactory.

On her natural-draft six hours' trial, April 19, the *Puglia* made a mean of 4,900 I. H. P. and 17.6 knots. Forced draft, one and a half hours, she made 7,500 I. H. P and 19.5 knots mean. The maximum natural-draft horsepower was 5,250, just 1,000 over the contract. The firm of Orlando made the engines.

FULMINE.

The official trials of the destroyer *Fulmine* gave the following results: Six hours' trial with natural draft, 315 revolutions; I. H. P., 3,000; mean speed, 23.7 knots; three hours' trial with forced draft, 354 revolutions; I. H. P., 4,730; mean speed, 26.2 knots. A maximum speed of 26.5 knots was maintained for some time.

CONDOR.

The results of the official trials of the destroyer *Condor* are as follows: Trial of six hours' natural draft, water column about one-half inch, engines to develop not less than 1,800 I. H. P. with the use of liquid fuel, or 1,000 I. H. P. in case coal was used. Mean draught, 4 feet; mean speed, 20.8 knots; I. H. P., 1,157 (liquid fuel not being used); revolutions, 258; steam pressure in boilers, 175 pounds; coal consumption, 2.66 pounds; consumption per square foot grate surface, 30 pounds; temperature in boiler room, 115° F., in engine room, 109° F.

Full power trial, three hours with forced draft, air pressure not to exceed 3 inches water; under these conditions the engines to develop not less than 2,400 I. H. P.; mean draught, 4 feet 1 inch; mean speed, 25.7 knots; maximum speed, 26.3 knots; I. H. P., 2,410; revolutions, 341; air pressure, 1.7 inches; steam in boilers, 196 pounds; in steam pipes, 173 pounds; vacuum, 25.75 inches; temperature in both engine and boiler rooms, 106° F.; consumption, selected Cardiff coal, 2.71 pounds; per square foot of grate, 62 pounds; total coal burned per hour, 5,028 pounds.

The results of this trial are noteworthy in that without hard forcing and with an air pressure of less than 2 inches of water instead of the 3 inches allowed by the contract, the full designed power of 2,400 I. H. P. was obtained.

After the full-power trial, a second natural-draft trial was made with an air pressure of one-half inch of water in order to compare with the previous results, and to note what advantage in these conditions might arise from the change in the method of forced draft on the closed ashpit system. The results showed a marked advantage, 1,500 I. H. P. being developed with 285 revolutions, giving a speed of about 22 knots, instead of 20.8. It was also found that the consumption of coal per I. H. P. per hour was reduced to 2.16 pounds.

From the results of a series of progressive trials held subsequently, it appears that the highest value (0.649) of the propulsive coefficient is reached at a speed of 21 knots, corresponding to the development of about one-half of the full power, and that the efficiency at higher speeds up to the maximum of about 26 knots is maintained at values above 0.60.

LAMPO.

The destroyer *Lampo*, of 320 tons, built by Schichau, continued her trials. With 5,998 I. H. P. she made 340 to 350 revolutions and 31.17 knots. On a consumption trial of six hours at 25 knots, she used 1.808 pounds of coal per horsepowerhour, which is a little better than was predicted.

BRAZIL.

MARESCIALLO DEODORO.

The ironclad *Maresciallo Deodoro* made her first official run the 2d of August last. The draught of water was about 12.92 feet, with a displacement of 3,082 tons. With fine weather, calm sea, and an easterly breeze, the measured base was run over four times. The speed attained during the last run was 14.952 knots, being about a knot in excess of the required speed. The mean of the last two runs was 14.876 knots. At this speed a complete circle was turned in four minutes and a quarter.

On August 5, a coal-consumption trial was made at 10 knots' speed, and in place of a consumption of 1.46 allowed by the contract, the consumption did not exceed 1.21 pounds.

TAMOYO.

The new torpedo cruiser *Tamoyo*, built at the Germania Yard, Kiel, completed her steam trials successfully; under forced draft during a four hours' run, the engines developed 7,500 I. H. P., giving a mean speed of 22.7 knots, while during an eight hours' run under natural draft the engines developed 5,000 I. H. P., which gave a mean speed of 20.5 knots. The dimensions of the ship are as follows: Length, 269 feet; beam, 28 feet 10 inches; draught, 9 feet 10 inches; with a displacement of 1,080 tons. The armament consists of two 10.5-centimeter (3.9-inch) guns, six 57-millimeter (2.2-inch), two 1.4-inch machine guns, all R. F., and two mitrailleuses, with three submerged tubes for 18-inch torpedoes. There is an armored deck 1 inch thick on the slopes and three-eighths inch on the horizontal part in addition to protection afforded by the coal bunkers. The bunkers can stow 260 tons, which, at 10 knots speed, give a radius of action of 6,000 miles.

HOLLAND.

In the trial trips held during the autumn of 1899, one of four hours at full speed, the other of thirty hours at sea, all three of the new

Netherlands cruisers came up to contract requirements. Specifically the results were as follows:

	Noord Brabant.	Gelderland.	Utrecht.
Full speed trial:			
Average I. H. P	10,040	9,867	10,067
Speed, knots	20.08	20.047	19.618
Coal consumption per I. H. P. per hour, pounds	2.07	2.49	2.20
Thirty hours' trial:			
Average I. H. P	4,690	4,346	4,533
Speed, knots	16	16	16
Coal consumption per I. H. P. per hour, pounds	1.98	2.27	2.37

The engines of all three were built at the Nederlandsche Fabrick at Amsterdam.

NEW SHIPS AND TORPEDO BOATS.

FRANCE.

HENRI IV. (A-3.)

(Page 155, No. XII; 45, No. XIII; 18, No. XIV; 28, No. XV; 27, No. XVI, Part II.)

DESCRIPTIVE AND EXPLANATORY REMARKS.

Battleship, for coast defense, improvement on *Bouvines* class. High forecastle, the sides are brought in, no longer following the water line, but a straight line fore and aft inboard, forming a narrow superstructure as compared with the full beam of the ship; from where the forecastle ceases the freeboard is very low, especially aft, where it is only 3 feet 6 inches out of the water. Freeboard forward about 21 feet.

The keel was laid at Cherbourg dockyard, July 15, 1897, and she was launched August 23, 1899.

Material of hull, steel; form of bow, ram (slight); two funnels; one military mast forward and signal mast aft; complement, 26 officers and 438 men.

Dimensions: Length, 354.3 feet; extreme breadth of beam, 72.84 feet; draught, maximum, 22.96 feet; displacement, 8,948 tons. Cost: Total, $3,813,927; guns, $303,245; torpedo outfit, $35,604.

ARMAMENT.

Two 274.4-millimeter (10.8-inch) guns in turrets forward and aft.

Seven 138.6-millimeter (5.45-inch) R. F. guns, four in central redoubt, two in casemates at sides above it, and one in after turret.

Twelve 47-millimeter R. F. guns on superstructures.

Two 37-millimeter R. F. guns in military top.

Two 65-millimeter R. F. guns on field mounts.

Torpedo tubes, two—submerged.

Distribution of guns: (There is one complete deck above the water line, which is the upper armored deck; above this main deck are three decks, two of which extend to the bow, but not to the stern; these, for convenience, may be termed the battery, upper, and bridge decks): One of the two turrets for the 10.8-inch guns is situated forward on the bridge deck, giving its gun an arc of train of about 145 degrees on either side of the bow, firing over the forecastle; the other 10.8-inch gun is located in a similar turret aft on the end of the battery deck, which is some distance from the stern. This gun trains about 150 degrees on either side of the stern.

Across the battery deck amidships is a central armored redoubt, with corners cut away. The four 5.45-inch guns situated in these corners have, therefore, a train of 120 degrees each—that is, from right forward in the case of the two forward ones and right astern in the case of the two after ones to 30 degrees abaft and forward of the beam, respectively. Above this redoubt on either side is a casemate, each containing a 5.45-inch gun, having a training arc of 65 degrees on either side of the beam. The seventh 5.45-inch gun is located in a turret placed on the after end of the upper deck, and fires through a large arc on either side of the center line of the ship, over the turret of the after 10.8-inch gun.

All the turrets and ammunition hoists are worked by electricity.

PROTECTION.

Hull protection: Harveyized steel belt from stem to very near the stern, with a thickness of 11.8 inches amidships, 7 inches at ends. Width, 7.22 feet—2.95 feet above and 4.27 feet below water line. After transverse bulkhead uniting ends of belt, 9.84 inches thick. Side armor above this extends from bow to central redoubt—with a width of 7.38 feet, on redoubt 14.76 feet; thickness, 3.78 inches. Bulkheads across ends of redoubt 3.78 inches thick.

Protective deck: Lower curved deck, 1.97 to 3.15 inches thick; splinter deck flat, 1.26 inches thick.

Turrets, barbettes, redoubts: Central redoubt, casemate above it and turret for after 5.45-inch gun, have 4-inch armor; two main turrets forward and aft have 9.5-inch armor, and their hoods 11.8-inch armor.

MOTIVE POWER.

Engines: Made at the Indret Engine Works; three in number, in separate compartments, divided by water-tight bulkheads. Vertical triple-expansion engines. To develop 11,500 I. H. P., giving speed of 17 knots. Maximum I. H. P., 12,000.

Boilers: Niclausse water-tube boilers, divided into four groups, placed two and two before and abaft the transverse bulkheads—12 in number. Maximum steam pressure, 294 pounds; heating surface, 25,940 square feet; grate surface, 807.3 square feet; height of funnels above grate bars, 73.5 feet.

Screws: Three.

Coal capacity: At load water line, 725 tons; total capacity, 1,100 tons.

Radius of action: At maximum speed, with 725 tons coal, 1,120 miles; with 1,100 tons of coal, 1,700 miles; at 10 knots, with 725 tons coal, 5,000 miles; with 1,100 tons coal, 7,590 miles.

DUPLEIX, DESAIX, KLÉBER.

DESCRIPTIVE AND EXPLANATORY REMARKS.

Armored cruisers, derived from the *Jeanne D'Arc*, diminutions of the *Gueydon* class. Designed for service on foreign stations.

The *Dupleix's* keel was laid at the Rochefort Arsenal January 18, 1899, and she was launched April 28, 1900. The *Desaix*, to be built at the Loire shipyards, St. Nazaire, and the *Kléber* at the Gironde shipyards, Bordeaux, are not as yet laid down.

Material of hull, steel, sheathed and coppered; form of bow, slight ram; four funnels fore and aft, in pairs; two pole masts; complement, 480.

Dimensions.—Length, 426.5 feet; extreme breadth of beam, 58.4 feet; draught, 24 34 feet; displacement, 7,700 tons.

Cost.—Total, $3,022,200; hull and machinery, $2,599,164; guns, $402,347; torpedo outfit, $20,690.

ARMAMENT.

Ten 6.48-inch guns. Two of these are mounted in turrets on the center line fore and aft, on the upper deck, having large arcs of fire. The rest are mounted, four on each broadside, in armored casemates, on the main deck. Four of these eight in casemates have direct fire ahead, and four have direct fire astern, by reason of the sides of the ship being brought inboard amidships and the casemates placed on sponsons. Ten 47-millimeter R. F. guns; six mounted on the upper deck over the four forward and the two after casemates, and the other four on the lower deck, firing through recessed ports nearly abreast of the forward and after turrets of the larger guns.

Six 37-millimeter R. F. guns, two on the forward bridge, two on the after bridge, and two on the main deck, well aft.

(The above data concerning the guns is derived from authoritative sources. It is otherwise stated as follows: Eight 6.48-inch guns by couples in four turrets—one forward, one aft, and one in each waist; four 3.94-inch guns; ten 47-millimeter and four 37-millimeter guns).

Two 65-millimeter guns.

Torpedo tubes, two, above water.

Search lights, six.

PROTECTION.

Hull protection: Steel belt 3.94 inches thick extends from the stem to about 65 feet from the stern. It rises about 3.28 feet and descends about 3.94 feet from the water line, and toward the bow rises to a height of 9.84 feet above water. The vertical armor is not secured on a wood backing. A peculiarity of these vessels is a strip of hard steel armor secured to the protective deck nearly down at the sides, with a thickness of about 1.4 inches. Cofferdam around water line just inside of armor, extending full height of the space between the two decks covered by the belt.

It is proposed to fill the cofferdam with an obturating material. Inboard of the cofferdam is a passageway. On the first deck above the belt there are fitted on each side partial partitions extending inboard from the sides of the vessel, and producing the effect of a number of wide stalls. These are fitted on the *Jeanne D'Arc* and vessels similar to her, and are made of metal not thicker than 0.08-inch, and have a beading on the inboard edge. They are placed at every fourth beam and extend nearly the entire length of the deck, being discontinued only at the ends, where the sides begin to curve markedly toward the bow and stern. They are intended to localize water in case the vessel should take a marked heel through injury in battle. They are secured inboard to a fore-and-aft strip about 18 inches in height.

Protective deck: Thickness on the horizontal part, 1.77 inches; on the slopes, 2.76 inches,

Turret armor 5.5 inches thick.

MOTIVE POWER.

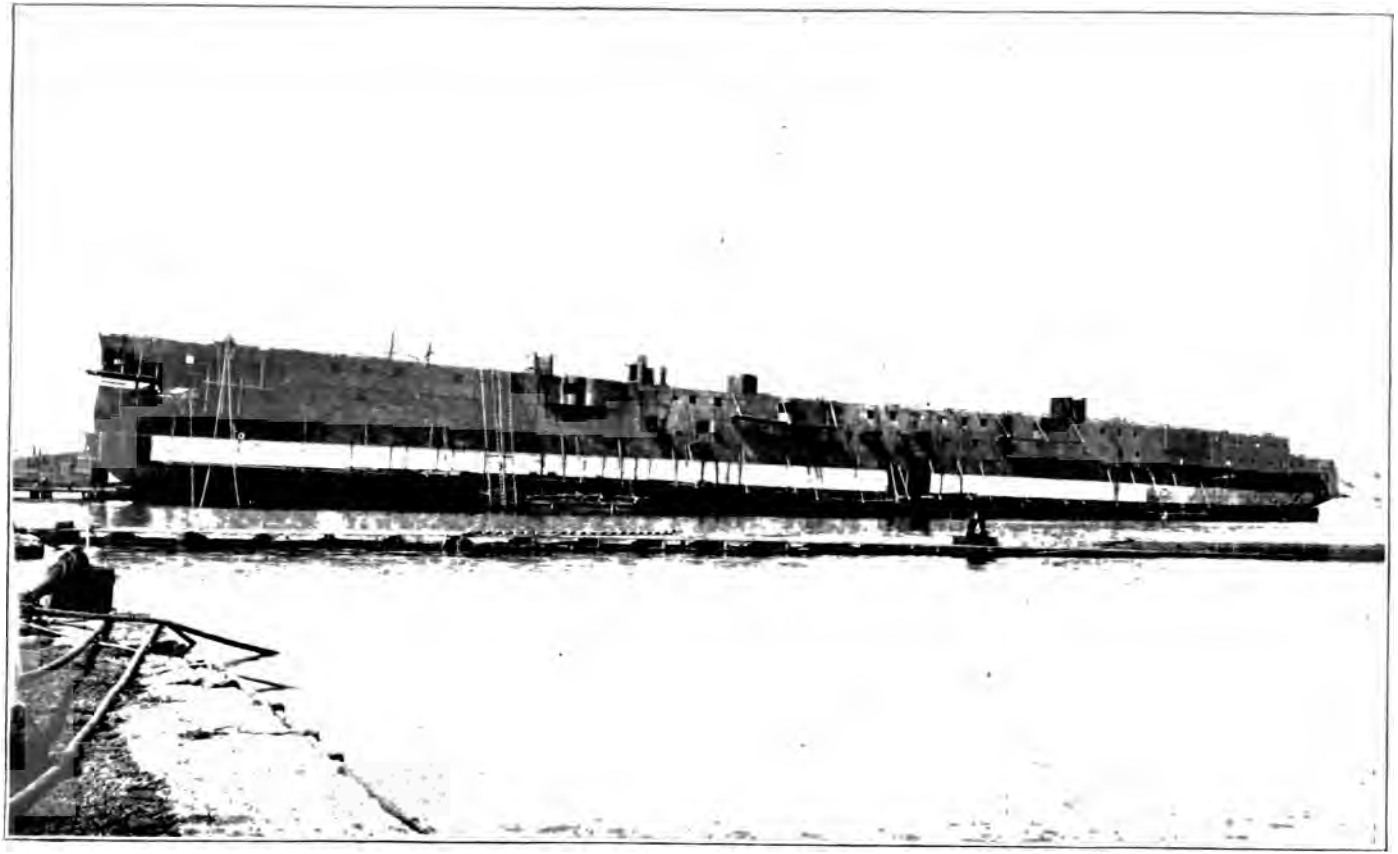
Engines: Three vertical triple-expansion engines, installed in separate water-tight compartments, together forming a single transverse section of the ship. Three screws, I. H. P. 17,100 at 150 revolutions.

Boilers: The *Dupleix* and *Desaix* are to have 24 Belleville boilers each, placed in eight boiler rooms, with a total grate surface of about 1,076 square feet. The *Kléber* is to have 16 Niclausse boilers, also in eight boiler rooms.

The auxiliary machinery includes five electric ammunition hoists and two 600-ton exhaust pumps. Three dynamos furnish power for the machinery which operates the turrets and the ammunition hoists, as well as for the six search lights.

The engines of all these new French cruisers are placed in the middle of the length of the vessel, and the boilers both forward and abaft them.

The stern is much cut away, and the rudders do not rest on a step. The side propellers are widely separated from the center one. This separation of the engines has necessitated giving a special shape to the frames under them, making them in places considerably less in depth than adjacent frames.



MONTCALM. (France, armored cruiser.) 9,516 tons; I. H. P., 19,600; speed, 21 knots; launched, 1900.

Coal capacity, at load water line, 880 tons; total capacity, 1,200 tons; giving a radius of action, in the first case, of 1,216 miles at maximum speed and 6,450 miles at 10 knots speed, and, in the second case, of 1,650 miles at maximum and 8,800 miles at 10 knots speed. The required speed is 21 knots.

Anchors: These new cruisers are fitted with "patent anchors," and the two bower anchors are stowed in recesses built into the bows. A third anchor of the same model is stowed well forward on the forecastle.

MONTCALM.

(Page 10, No. XVII, Part I.)

The armored cruiser *Montcalm*, laid down January 25, 1898, was launched March 27, 1900. In all essential respects she is a sister to the *Gueydon*, building at Lorient and launched in September, 1899, and the *Dupetit-Thouars*, now building at Toulon. The *Montcalm* is building by Les Forges et Chantiers de la Méditerranée at La Seyne, and is fitted with 20 boilers, 4 being of the simple Normand and 8 of the double Normand-Sigaudy type, differing in this particular from the *Gueydon*, which has 28 Niclausse boilers, and from the *Dupetit-Thouars*, which has 28 Belleville boilers.

A general description of the *Gueydon* on page 90 of General Information Series, No. XVIII (except as it states erroneously the kind of boilers for the *Gueydon*), applies equally well to the other two ships of this class. Fuller details are as follow:

There are four complete decks—the protective deck, at the water line; the upper protective or gun deck; the main deck; and the upper or spar deck, which is not carried out to the stern.

ARMAMENT.

Distribution of guns: The two 7.64-inch guns, having an arc of fire of 270 degrees, are placed in closed barbette turrets on the upper deck, one forward and the other aft, armored as follows: Moving portion: walls, 7.87 inches; dome of turret, 1.18 inches; splinter screen, 1.575 inches. Fixed portion: parapet, 7.87 inches; splinter-screen floor, 1.575 inches; upper part of ammunition hoists, 6.3 inches; lower part, 1.97 inches. Elevation by hand; training by electricity or hand. Distinct projectile and powder hoists.

Eight 6.47-inch R. F. guns, four on each side of the main deck on sponsons, with casemates having 4.72 inches of steel in front, 1.97 inches in rear, 1.18 inches underneath, and a roof of 0.87-inch steel. Each has a separate ammunition hoist, actuated by electricity or by hand. The two after and two forward 6.47-inch guns can fire in line with the keel.

Four 3.94-inch R. F. guns on the upper deck, behind strong steel shields, and each with a separate ammunition hoist.

Sixteen 47-millimeter guns, R. F.: Four in the military top, six on the upper deck and bridges, and six in the battery.

Six 37-millimeter guns, R. F., upon the bridges and on the main deck aft.

The 47-millimeter and 37-millimeter guns are served by three ammunition hoists actuated by hand, one in the military mast, one for the pieces forward, and one for those aft.

There are said to be installed two submerged torpedo tubes and three above water. The two submerged tubes are on each broadside forward. The torpedo rooms are located forward.

The distribution of fire, therefore, is as follows:

Ahead: One 7.64-inch; two 6.47-inch, R. F.; two 3.94-inch, R. F.; four 47-millimeter, R. F.; two 37-millimeter, R. F.

Astern: One 7.64-inch; two 6.47-inch, R. F.; two 3.94-inch, R. F.; six 47-millimeter, R. F.; four 37-millimeter, R. F.

Broadside: Two 7.64-inch; four 6.47-inch, R.F.; two 3-94-inch, R. F.; eight 47-millimeter, R. F.; three 37-millimeter, R. F.

PROTECTION.

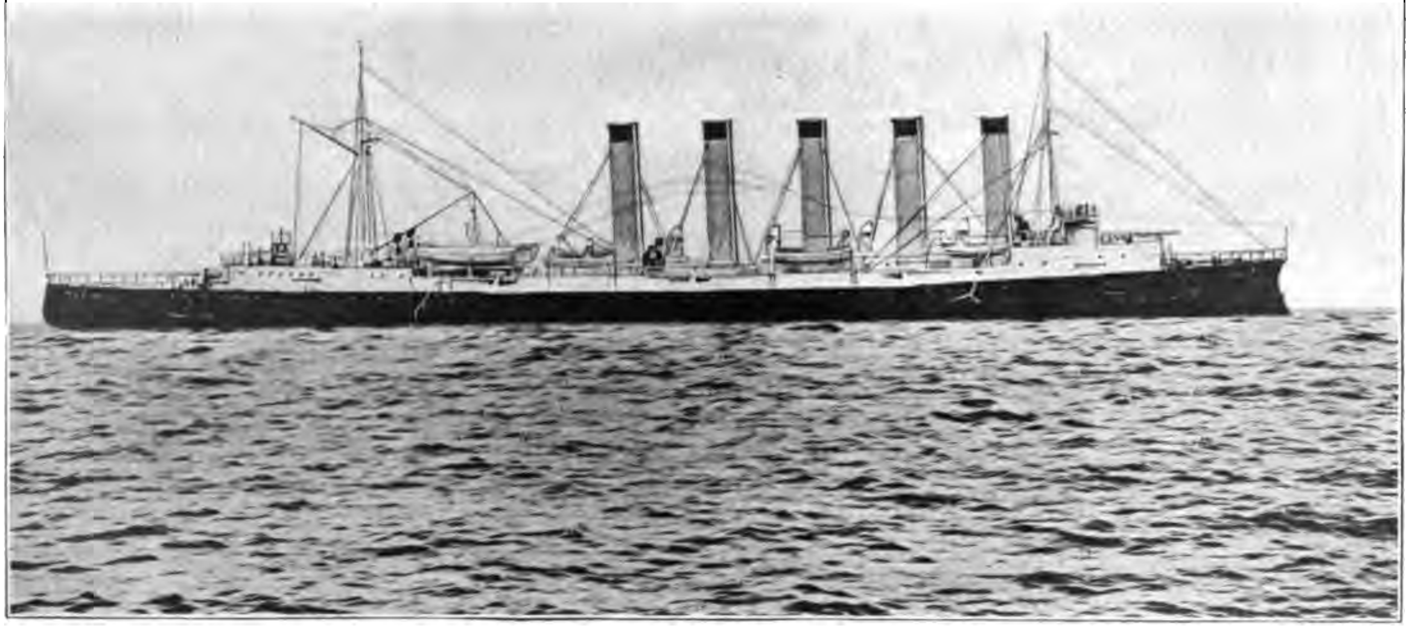
Hull protection: At the water line the main armor belt extends from the stem to within 13.12 feet of the stern, where a transverse bulkhead unites the ends. This belt rises 2.36 feet above and descends 4.43 feet below water, except at the stern, where the depth below water is only 2.36 feet; its maximum thickness is 5.91 inches, decreasing to 3.54 inches forward and to 3.15 inches aft.

Above this main belt a slighter belt extends over the same length and rises to the level of the upper armored deck, thus protecting the space between the two protective decks (the "tranche cellulaire"); its thickness is 3.74 inches amidships, decreasing to 3.35 inches forward and 2.95 inches aft.

Still another belt is laid on for a distance of 141 feet, beginning at the stem (to a point in line with the first funnel forward), rising to the level of the main deck, 2.24 inches thick at its lower edge and 1.58 inches at its upper edge.

The bulkhead forward of the forward casemates has armor 4.72 inches thick, that aft of the after casemates 3.94 inches thick. The bulkhead aft which limits the two side armor belts has armor with a thickness at its lower edge of 3.31 inches and at its upper edge of 1.58 inches. The two former bulkheads rise from the main deck to the upper deck, and thus serve as protection to the 6.47-inch guns between decks from raking fire. The after bulkhead descends to the hull.

The hull is very much subdivided by water-tight bulkheads and has a double bottom. An ingenious combination of partial bulkheads at the sides below the protective decks affords a great amount of protection, even in certain critical circumstances. In the sides of the "tranche cellulaire" and around all large openings is a cofferdam.



ASKOLD. (Russia, protected cruiser.) 7.962 tons; I. H P., 19,000; speed 23 knots; launched. 1900.

Protective decks: The lower protective deck is composed of a horizontal part in the center with a thickness of 1.18 inches, and of sloping sides, the thickness varying from 2.17 to 1.18 inches at the sides, which meet the lower edge of the main belt armor.

The upper protective deck, at the height of the upper edge of the second armor belt, is composed of one layer of a thickness of 0.394 inch, except between the turrets, where it is of a total thickness of 0.63 inch, in two layers. This deck is flat.

Conning tower: elliptical, with armor 6.3 inches thick. Situated on the forward bridge. Voice tube has 4.72 inches of armor.

MOTIVE POWER.

The ship is driven by three screws, each actuated by a vertical, triple-expansion engine, each with three cylinders. Normal I. H. P., 10,000; maximum, 19,600, with 135 revolutions; speed, 21 knots.

The normal coal supply is 1,020 tons; the bunkers can carry 1,600 tons. Provision is also made for petroleum fuel, contained in four cisterns, two forward and two aft; the capacity of each is 20 tons.

The engines are placed side by side in the same transverse space, but this is divided into three water-tight compartments by longitudinal bulkheads.

The boilers are placed in four transverse boiler rooms, two forward of and two abaft the engines.

ELECTRICAL APPARATUS.

Four steam dynamos, running at 400 ampères, 82 volts, with the ability to run for an hour at 500 ampères, 82 volts, actuated directly by vertical compound engines, running at 350 revolutions a minute. For interior lighting there are about 500 lamps.

One search light is located on a platform at the top of the military mast, one on a platform low on the mizzenmast, and four are placed in the battery—two forward and two aft—mounted on traveling railways, and rig in and out.

Boats.—The ship has 18 boats.

Crew.—In case of a general officer and staff being aboard, the crew will number 610 men, about 24 being officers.

Cost.—The total cost of the *Gueydon* is estimated to be about $3,961,665, of which $436,206 is for the guns and $35,604 for torpedo armament.

RUSSIA.

ASKOLD.

(Page 51, No. XVIII.)

On March 15, 1900, the protected cruiser *Askold* was launched from the Germania Works at Kiel. The ship has noticeably slender lines, a powerful armament, large coal supply, and a strong water-tight subdivision throughout. On the upper deck is a superstructure containing the officers' quarters, and forward another for the closets, baths, etc., of the crew. Over the forward house is a roomy conning tower with 5.9 inches of hardened nickel-steel Krupp armor, and above it the bridge. The bow has a ram form; there are five tall, slender funnels in a fore-and-aft line, and two light pole masts rigged for signaling purposes.

ARMAMENT.

Twelve 15-centimeter (5.9-inch) guns, one forward on top of the deck house, one aft on the upper deck, and five on each side in sponsons on the upper deck, all training through considerable arcs. These are rapid-fire 45-caliber guns.

Twelve 7.5-centimeter (2.95-inch) R. F. 50-caliber guns, all on main deck, two forward, two aft, and eight in broadside. The four forward ones are mounted in sponsons, giving them a direct fire ahead, and the four after ones are similarly mounted, giving them astern fire.

Eight 47-millimeter (3-pounder) and two 37-millimeter (1-pounder) R. F. guns, besides two machine guns, on the bridge and superstructures.

There are six torpedo tubes for 38-centimeter torpedoes, 1 forward above water, two on broadside above water, two broadside under water, and one astern.

The ship has torpedo net defense rigged on spars.

The armor protection for the 5.9-inch guns is 5 inches thick.

Six searchlights, Mangin system, are carried, two forward on the superstructure, two on the after superstructure, and two amidships.

Latest obtainable information has it that the *Askold*, instead of being supplied with two sets of engines, as stated on page 52, No. XVIII, and twin screws, has an installation of three sets of triple-expansion engines, driving three screws, the two forward ones in a single compartment, the after one in a room by itself, the mean speed to be at least 23 knots an hour on a twelve hours' endurance trial. On the measured mile, or during a three hours' run, the builders hope for a mean speed of 24 knots.

Steam is supplied by nine Schulz water-tube boilers in five watertight compartments below the water line.

Six dynamos, of which four are located beneath the protective deck, furnish power for the interior lighting, auxiliary engines, and the searchlights.

Each of the principal compartments has a centrifugal pump, run by a separate electric motor, capable of emptying the compartment in one hour.

The Krupp firm have furnished everything for the *Askold*—hull, armor, boilers, engines, and armament. It is reported that no other firm in Germany is able to do this.

It is said that it will be a difficult matter to berth her crew of 580 men, especially the engineer personnel, which will necessarily be large.

BAYAN.

The armored cruiser *Bayan*, launched at La Seyne by Les Forges et Chantiers de la Méditerranée in June, 1890, presents the following characteristics:

Length, between perpendiculars, 445 feet; breadth of beam, 57 feet 1 inch; depth of hold, 38 feet; mean draught, as well as maximum, 22 feet 1 inch; displacement, 7,800 tons.

The following details will show that the displacement, relatively small, has been admirably utilized in the *Bayan*, and that the vessel possesses important military value in spite of its reduced displacement. The hull is built of steel, sheathed, and presents a distribution worthy of notice. A double bottom extends under the engine and boiler spaces to the height of the armored deck. The various compartments are separated by longitudinal bulkheads, forming on both sides a third protection. Under the armored deck are two between decks, the lower one, surrounded by a cofferdam, is divided by several longitudinal and transverse bulkheads, these forming a complete horizontal cellular section, which effectively protects the vessel against sinking in the case of water entering above the armored deck. These compartments, with the exception of the forward and after ones, are used as coal bunkers. The upper between decks contains the cabin of the captain and some other officers, besides the military installations, which will be mentioned hereafter.

The defensive power consists of a nearly complete armor belt 5.9 feet in width, reaching 3.9 feet below the water line, and rising 2 feet above. The armor is made of cemented steel plates 7.9 inches in thickness at the upper edge, and 3.94 inches at the lower edge, over all the space containing the engines and boilers. Forward of and abaft this space the thickness decreases gradually to 3.94 inches at the extremities. The main water-line belt is further strengthened by a thinner plate of special steel, covering the entire height of this cellular between decks. Over the above plate are three redoubts, with protective plates 3.2 inches thick, placed forward, aft, and abeam for intermediate and small-caliber guns. The armored deck reaches to the lower edge of the all-round belt and has an effective thickness of 2 inches in the unarmored water-line space aft. The protective deck, which reaches below the water line, is topped by a cellular division whose upper facing is on a level with the armor deck.

The heavy guns in the turrets are protected by plates of armor 6.6 inches thick in both the movable and fixed parts. The speaking tube is 3.2 inches thick. The conning tower is protected by plates 6.3 inches thick.

To the efficient protection of the whole the *Bayan* joins a considerable offensive power. The armament that constitutes it is distributed as follows:

Two 8-inch guns in the forward and after turrets. The forward gun is raised 3 feet higher than the after gun. The turrets are balanced and worked by electricity and hand.

Eight 6-inch guns distributed as follows: Two in the forward redoubt, four in the central redoubt (one at each corner), and two in the after redoubt. These guns are, in addition to the plates of the redoubts, protected by circular shields.

Twenty 12-pounder guns distributed as follows: Eight in the central redoubt in broadside, four on each side; two in the bows; two at the stern; four on the central redoubt above the four 6-inch guns (chase and retreat); two on the forward redoubt above the 6-inch guns (chase); and two on the after redoubt above the 6-inch guns (firing astern).

Seven 47-millimeter rapid-fire guns in the tops and on the superstructure available for boat armament.

The guns are so distributed that it is possible to concentrate forward and aft simultaneous fire of one 8-inch gun, four 6-inch guns, and six 12-pounders, besides the Hotchkiss machine guns.

The magazines are situated right under the pieces they serve, and can stow 100 rounds of 8-inch, 150 of 6-inch, 750 of 12-pounder, and 500 of 47-millimeter. The ammunition is handled by hand and electricity. There are also two submerged torpedo tubes, firing at an angle of 65 degrees.

The motive power is provided by two triple-expansion engines of 17,000 I. H. P., supplied by 26 Belleville boilers, with economizers, distributed in four rooms. The speed required by the contract is 21 knots in a sustained run of twenty-four hours. Coal capacity, normal, 750 tons; maximum, 1,100. The coal is stowed in most part in bunkers around boilers. There are other lateral transverse bunkers to facilitate the service of the boilers.

The engines were built in Marseilles and the boilers at St. Denis.

The cost was 16,500,000 francs.

ITALY.

It is reported that Minister Bettolo has decided on the following four figures as the principal data for the new cruisers, two of which will probably soon be laid down: Speed, minimum, 22 knots; armor, not less than 6 inch; armament, twelve 8-inch, twelve 3-inch, and twelve 47-millimeter guns; displacement, 7,500 to 8,000 tons.

The plans for the new type of ship are being studied by Naval Constructor Cuniberti, who has determined the defensive and offensive characteristics as follows:

Defensive characteristics.—Armor belt from bow to stern, armored redoubt, bulkheads, casemate turrets, and conning towers, not less than 6 inches thick, able to keep out any high-explosive shell, of whatever caliber, and the armor-piercing shell of the largest rapid-fire guns with which battleships have hitherto been armed.

Offensive characteristics.—The armament to exceed 6-inch caliber, which has proved inadequate against armored ships. At battle distances the twelve 8-inch guns will be able to perforate hostile armor.

Speed and autonomy.—The speed of the present armored cruisers is not sufficient for the services which they may be called upon to render in war, hence the speed must exceed 22 knots.

REPORTED CHANGES IN PLANS OF BENEDETTO BRIN AND REGINA MARGHERITA.

Four 30.5-centimeter (12-inch) guns to be installed in the four corners of the quarter deck; twelve 15.2 centimeter (6-inch) guns on the gun deck, the four guns at the extremities being adapted to fire ahead and astern; twenty-four 7.6-centimeter (3-inch) guns on the gun deck, forward and aft, on the superstructures, and in the fighting tops. (Original plans: Two 30.5-centimeter (12-inch) guns in one turret, aft; ten 20.3-centimeter (8-inch) guns installed in pairs in five turrets, one in the bow, the other four in the broadsides at the corners of the armored citadel.)

The armor is 15 centimeters (6 inches) thick at the belt and 20 centimeters (8 inches) in the bulkheads, which close the redoubt in the orlop and gun deck.

The protective deck extends from bow to stern, and is 20 millimeters (0.787 inches) thick on the horizontal part and 80 millimeters (3.15 inches) on the slopes.

The motive apparatus, which is being constructed by the Ansaldo Company is to develop 19,000 I. H. P. and give the ships a speed of 20 knots.

The following are the dimensions of the hull: Length between perpendiculars, 426 feet 6 inches; length over all, 454 feet 9¼ inches; extreme breadth of beam, 78 feet 2¼ inches; mean draught, 27 feet ½ inch. Normal displacement, 13,426 tons.

This change from 8-inch to 6-inch guns on these battleships seems very inconsistent with the design of the new 8,000-ton ships, in which the 8-inch gun appears, the principal argument for it being that the 6-inch gun is too small.

FLOTILLA OF DESTROYERS.

Italy having decided upon the construction of a flotilla of destroyers, the *Fulmine* was ordered from the firm of Odero, at Sestri Ponente, from whose yards she was launched on December 4, 1898. Before proceeding with further construction, Italy apparently awaited the results to be obtained by a division torpedo boat, *D–10*, built in England for the German Government. The especial point involved in ordering this boat from English builders was to obtain a comparison of English with German built boats of the same type. The results of the trials of *D–10* were such that Germany ordered from Schichau a number of destroyers, and at the same time Italy gave the same firm orders for six boats. A second order was placed with Pattison, at Naples, for six boats, constituting a third type.

It is most likely that the *Fulmine* will not be repeated.

The two classes under construction, then, are the *Aquilone*, *Borea*, *Nembo*, *Turbine*, *Meteora*, *Tuono*, at Naples; *Dardo*, *Freccia*, *Lampo*, *Strale*, *Euro*, *Ostro*, at Elbing.

The characteristics are:

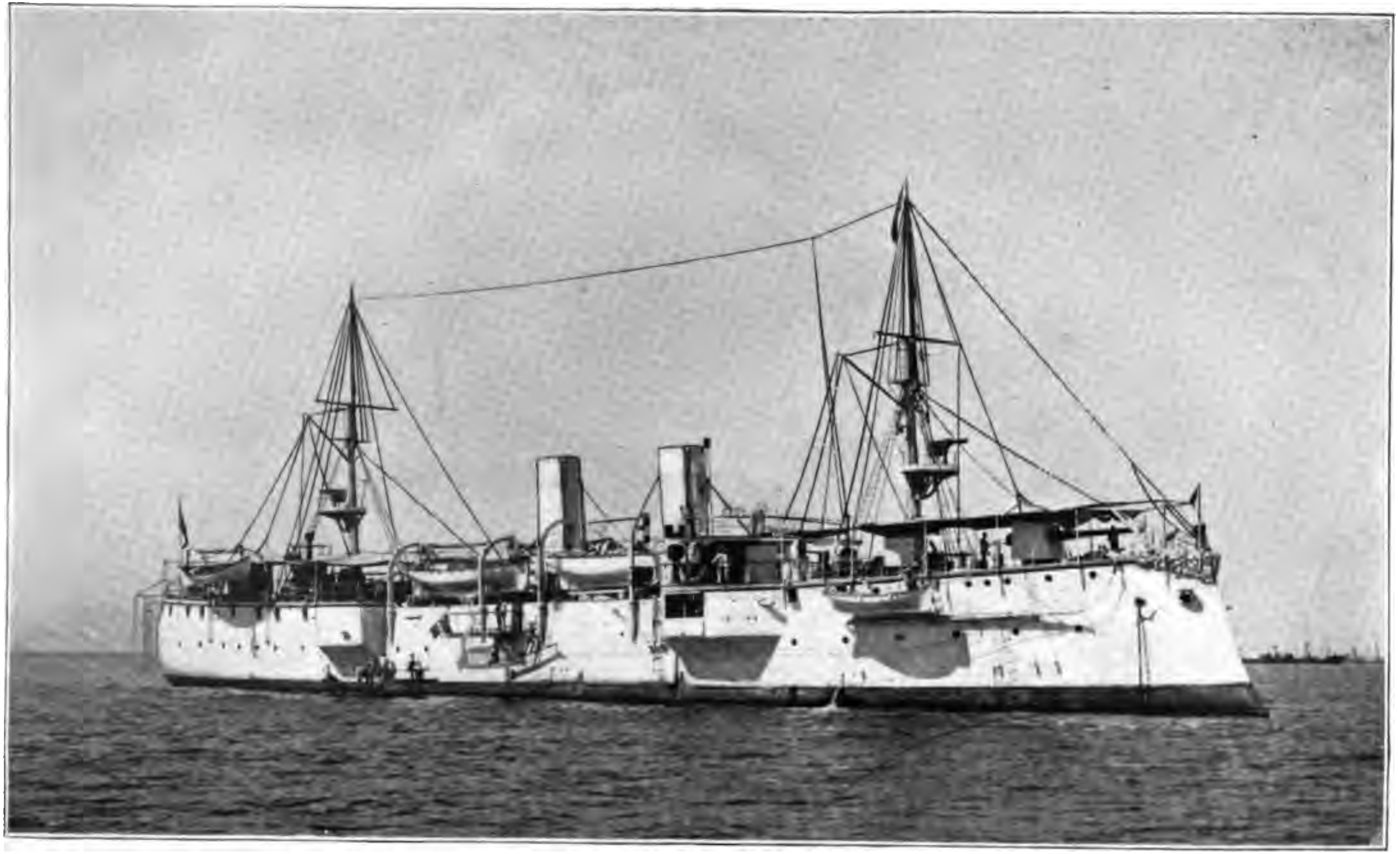
	Fulmine.	Lampo.	Borea.
Material of hull	Nickel steel.	Steel.	Steel.
Length between perpendiculars, feet	200	198.6	208
Greatest breadth of beam, feet	21	21.32	19.48
Draught forward, feet	6.2	5.74	6.33
Draught aft, feet	8.79	8.36	7.51
Displacement, tons	298	320	330
I. H. P	4,800	6,000	6,000
Twin screws.			
Coal capacity, tons	60	60	60
Speed, estimated	30	30	30
Guns, 76 mm	....	1	1
Guns, 57 mm	5	5	5
Torpedo tubes	2	2	2

Of the Schichau boats, two have been launched—the *Lampo*, October 8, 1899, and *Freccia*, November 23, 1899.

The hulls of the two types *Fulmine* and *Lampo* show very important differences. The lines of the stern are too fine in the former, and in consequence, at a speed of 26 knots, the taffrail descends from 1.20 meters to only 40 centimeters from the surface of the water, while the bow rises in such manner as to give to the ship an entirely abnormal water line, which is prejudicial to the speed. Except for that the *Fulmine*, with her 4,730 horsepower (she should develop 4,800) would certainly attain, if not exceed, a speed of 30 knots.

In the *Lampo* type, on the contrary, the stern sits well on the water. The line of flotation is not perceptibly changed and the power of the engine is better employed.

The motive power of the *Fulmine* consists of two triple-expansion engines, each having four cylinders. The two low-pressure cylinders are equal to each other and to that of medium pressure, and exhaust into a single condenser provided with two centrifugal circulation pumps, which are placed in the engine room. The condensed water is forced



RIO DE LA PLATA. (Spain, protected cruiser.) 1,875 tons; I. H. P., 7,100, speed, 20 knots; launched, 1898.

by special pumps into the purifying apparatus of the Rankine system (formed of tubes pierced with small holes and covered with coarse-meshed canvas, on which is deposited the grease which comes from the lubrication of the cylinders) and passes next into the Normand heaters, which receive the exhaust from the auxiliary engines.

The steamer is furnished with four water-tube boilers of the Blechynden type, placed in pairs in two separate compartments. Each compartment has two ventilators for forced draft in a closed receptacle. The compressed air reaches the grates by opening by its own pressure the automatic doors of the ash pits. Each boiler is fed by a special pump of the Blake type, and there is also in each compartment an auxiliary feed pump of the Worthington type. The normal working pressure of the boilers is 220 English pounds. The total grate surface is about 20 square meters and the total heating surface about 910 square meters.

The following results were obtained in the official trials:

Duration of trial with natural draft (hours)	6
Duration of trial with forced draft (hours)	3
Number of revolutions with natural draft	315
Number of revolutions with forced draft	354
Horsepower with natural draft	3,000
Horsepower with forced draft	4,730
Average speed per hour with natural draft (miles)	23.70
Average speed per hour with forced draft (miles)	26.20

During the trial with forced draft a speed of 26.5 knots was maintained for quite a long time.

SPAIN.

RIO DE LA PLATA.

The small protected cruiser *Rio de la Plata*, which was launched at Havre September 17, 1898, had her trials during the year 1899, and has been put in commission by the Spanish Government. This spring she paid a visit to Montevideo, the patriotic Spaniards of Argentina and Uruguay having subscribed the cost of the vessel.

In appearance she much resembles the Chilean *Pinto* and *Errazuriz*, save that she has two funnels, and is called an improvement on the type of the Spanish *Antonio de Ulloa.* She is built of steel, sheathed and coppered, has a high freeboard, a ram bow and two pole masts, each with a platform for a light gun.

Her principal dimensions are as follows: Length between perpendiculars, 245 feet 7 inches; beam, 35 feet 4 inches; mean draught, 14 feet 3 inches; displacement, 1,875 tons.

Two 5.9-inch R. F. guns are mounted, one on the topgallant forecastle and one on the poop, with box-like shields training with the guns. The forward gun trains through an arc of 290°, the after one, 244°.

Four 4.7-inch R. F. guns are mounted in broadside sponsons which project considerably outboard, giving the two forward guns a train from right ahead to several degrees abaft the beam, and the two after guns a train from right astern to some degrees forward of the beam.

Six 6-pounder R. F. guns are carried on the main deck in the waist, between the 4.7-inch guns.

Two 1-pounder Hotchkiss revolving cannon are carried on the forecastle, fitted with shields.

Four machine guns are carried, one in each top and one on each side of the forward end of the poop.

Two torpedo tubes above water, one on each beam abreast of the funnels.

For protection she has a light protective deck of mild steel, trapezoidal in section, having a thickness of 0.4 inch on the horizontal part and 0.8 inch on the inclined part. An armored conning tower on the bridge has a thickness of 0.8-inch steel on the sides and a roof of 0.6-inch, and the armored ammunition tubes from the protective deck to the upper deck have 0.8-inch thickness. She also has a cofferdam.

A search light is mounted on each end of the bridge, over the forward sponsons, and a third search light is mounted on a high platform over the poop.

Two sets of vertical triple-expansion engines, surface condensing, drive the two screws.

The steam-generating apparatus consists of two groups of Normand-Sigaudy water-tube boilers in four transverse water-tight compartments.

The ship carries two dynamos of 200 ampères capacity and 100 volts, which will supply electricity for incandescent lights and search-light projectors, as well as ammunition hoists and various auxiliary services. The ammunition hoists for the 5.9-inch and 4.7-inch guns are of the Noria type.

The vessel was designed for 7,100 I. H. P. and a speed of 20 knots with forced draft; 16.5 knots with natural draft. Her normal coal capacity is 270 tons, with which she is able to steam about 4,000 miles at 12.5 knots speed.

On her natural-draft trial she developed, it is said, 18.7 knots. She also made one attempt at a forced-draft trial and developed 19.6 knots. On this trial, however, her blowers did not work well and developed only a small fraction of their designed power. The vessel was, in all probability, accepted without an additional forced-draft trial, by reason of the excellent natural-draft speed developed.

The complement of the *Rio de la Plata* consists of 214 men.

Each engine room will be also in communication with the bridge and conning tower by means of the usual engine-room repeating telegraph.

The following boats will be carried: One steam lifeboat, 4 cutters, 2 gigs, 2 dinghys, and 2 punts for side cleaning.

Two weeks after this cruiser was laid down she was in frame up to the protective deck. The construction of this deck was pushed as rapidly as possible, considering the number of plates, which amounted to 118. From the protective deck to the upper deck the work proceeded rather slowly, due to the delay on the part of the contractors that were to supply the material. Without this delay it is probable that the ship would have been launched in eight months.

The principal part of the material used was supplied in Spain—the steel from the works of Altos Hornos y L. Felguera; the stem piece, stern piece, and rudder post from the Deusto Steel Works; the nickel armor from Vickers, the main engines from La Maquinista Terrestre y Maritima, the boilers from Vickers. The auxiliary motors and the anchor gear (the first engines of this class made in Spain), as well as the remaining machinery, were designed and built in the works of La Constructora Navale Española.

EL EXTREMADURA.

El Extremadura, the gift of Spanish citizens living in Mexico, was laid down February 22, 1899, and launched at Cadiz April 19, 1900. She is a protected cruiser of 2,030 tons displacement, constructed according to the latest models of vessels of the class. The hull is all of Siemens-Martens steel, with cellulose double bottom, and divided by bulkheads into 62 water-tight compartments.

Her dimensions are as follows: Length, 292.6 feet; beam, maximum, 36.09 feet; mean draught, 14.10 feet.

The most important defensive features are: A complete protective deck, made in two layers, each of 0.98-inch thickness. The bottom layer is of Siemens-Marten steel; the other, in the vicinity of the engines, of nickel steel. The conning tower and principal tube for voice tubes and interior communications are of nickel steel, 1.18 inches thick, and all the ammunition hoists for the main battery guns are protected by armor of special steel. The engines and main boilers are also protected by coal bunkers above and below the protective deck.

The armament consists of four 14-centimeter (5.51-inch) Hontoria R. F., with Canet carriages, placed in sponsons on the sides, to obtain maximum arc of fire ahead, abeam, and aft; four 10.5-centimeter (4.13-inch) Krupp amidships; four 47-millimeter Krupp forward and aft; two 37-millimeter Maxim-Nordenfeldt automatic guns on the bridges. All ammunition for the main battery will be hoisted by electricity.

Engines.—There are two vertical triple-expansion engines, with three cylinders each, capable of developing a combined I. H. P. of 7,000, with a maximum speed of 20 knots.

Boilers.—There are eight multitubular boilers of the Thornycroft type, to work at a pressure of 298.2 pounds per square inch, having a total heating surface of 17,506 square feet.

The capacity of the coal bunkers is sufficient for a radius of 6,000 miles.

Auxiliary machinery.—Besides the main engines, there are the following auxiliaries: Two centrifugal pumps, 4 Weirl pumps for supplying fresh water to the boilers, 2 duplex pumps for auxiliary fresh-water supply, 2 evaporators and 1 distiller, with necessary pumps; 2 reversing engines, 8 ventilators for forced draft, 4 ash hoists, 4 duplex pumps as bilge pumps for fire mains, 2 Downton pumps, 1 pump for drinking water, 2 electric motors for ammunition hoists, and 1 steam capstan.

The rudder will be turned by screw gearing, controlled by two cylinders with reversible valve, and manipulated from the bridge or conning tower.

Anchors worked by a vertical 2-cylinder engine, with necessary connections for its control from the forecastle or the compartment in which it is placed.

The compartments below the protective deck will be ventilated artificially by electric motors placed in bow and stern.

There are 135 electric lamps of 10 to 16 candle power, 2 search lights of 23.6 inches diameter, located on the bridge. The electric power supplied by 2 multipolar dynamos, Desrossier system.

The engines, magazines, dynamo room, and battery are in direct communication with the bridge and conning tower by means of voice tubes placed below the protective deck.

MINOR POWERS.

Some Second-Class Battleships.

While the first-class naval powers are pushing ahead with the construction of large battleships that attain a tonnage in some cases of over 15,000 tons, certain of the minor powers are developing a very interesting class of their own. These battleships of the second class are so similar in the several countries and possess such strong qualities of offense, defense, speed, and endurance that some descriptions, together with comparisons, are of value.

SWEDEN.

Name.	Length.	Beam.	Draught.	Displacement.	Speed.	I. H. P.	Armament.	Launched.
	Feet.	*Feet.*	*Feet.*	*Tons.*	*Knots.*			
Svea	248	48.6	17	3,100	14.7	3,650	Two 9.8-inch; four 4.7-inch; six 57 mm.; eight machine.	1886
Gota	258	48	16.7	3,200	16	4,750	Two 9.8-inch; six 5.9-inch; five 57-mm.; eight machine.	1889
Thule	261	48	17	3,300	16.2	4,740	Two 9.8-inch; four 5.9-inch; five 57-mm.; eight machine.	1892
Oden	278	48	17	3,500	16.5	5,390	Two 9.8-inch; four 4.7-inch; ten 57-mm.; four machine.	1896
Thor	278	48	17	3,500	16.5	5,350	Two 9.8-inch; six 5.9-inch; ten 57-mm.; four machine.	1898
Niord	278	48	17	3,500	16.5	5,350	.....do	1898
Dristigheten	285	49	16	3,500	....	....	Two 8.2-inch; six 5.9-inch; ten 57-mm.; four machine.	Bldg.
"A," "B," "C"	287	49	16	3,500	16.5	....	Two 8.2-inch; six 5.9-inch	Bldg.

NORWAY.

Harald Haarfagre	280	48	17	3,408	16	4,500	Two 8.2-inch; six 4.7-inch; six 12-pounder; six 1.5-pounder.	1897
Tordenskjold	280	48	17	3,408	16	4,500	.....do	1897
Norge	290	50	16	3,850	16.5	4,500	Two 8.2-inch; six 5.9-inch; eight 12-pounder; six 3-pounder.	1900
Eidsvold	290	50	16	3,850	16.5	4,500	.....do	Bldg.

HOLLAND.

Evertsen	283	47	17	3,520	16	4,735	Three 8.27-inch; two 5.9-inch; six 2.95-inch; eight 1.46-inch.	1894
Kortenaer	283	47	17	3,520	16	4,735	.....do	1894
Piet Hein	283	47	17	3,520	16	4,735	.....do	1894
Koningin-Regentes.	317	50	19	4,950	16	6,000	Two 9.45-inch; four 5.91-inch; eight 2.95-inch; four 37-mm.	Bldg.

DENMARK.

Herluf Trolle	272	49	16	3,470	15	4,200	Two 9.45-inch; four 5.91-inch; eight 37-mm.; two Maxims.	1899

BRAZIL.

Maresciallo Deodoro.	267	47	13	3,162	14	3,400	Two 9.4-inch; four 4.7-inch; four 57-mm.; two 37-mm.; two 25-mm.; two 6-inch howitzers; two 75-mm. field guns; two machine guns in tops.	1898
Maresciallo Floriano.	267	47	13	3,162	14	3,400	.....do	1899

SWEDEN.

SVEA, GOTA.

DESCRIPTIVE AND EXPLANATORY REMARKS.

Built by the Motala Engine Company, Stockholm. The two vessels are of the same type, but differ somewhat in dimensions. Information received in 1899 states that it is proposed to extensively reconstruct the *Svea*, *Gota*, and *Thule*, and in the following order: *Svea*, May, 1900; *Gota*, in the winter of 1900–1; *Thule*, 1901–2—the two latter ships on somewhat different plans from the *Svea*.

The *Svea* was launched in 1886 and the *Gota* September 30, 1889.

These two ships are built of steel, with ram bows, two short, thick, heavy funnels, elliptical in section, placed very close together in the fore-and-aft line. A single mast with a heavy military top, above which extends a light signal topmast. Extending aft from the mast to the stern is the superstructure in which are mounted all the guns smaller than the 9.8-inch turret guns. Immediately forward of the mast is the conning tower, above which is the navigating bridge and the sea pilot house. Forward of the conning tower is the turret containing the two 9.8-inch guns. From the turret the forward deck slopes down to the stem. Seen from outside, however, it presents the appearance of a straight line, on account of a hinged rail which lets down on clearing ship for action. It is reported that this arrangement has proven unsatisfactory in a sea way, in shipping water when the rail is up and of smashing the rail when hanging down, there being no way of securing them properly when the ship is cleared for action.

The anchors come into recessed hawse pipes, which do away with anchor davits, etc.

The steering gear is alike on the *Svea*, *Gota*, and *Thule*, and is arranged as follows: It consists of a yoke on the rudder post outside of the ship under water and worked by pistons operated by hydraulic power or steam. The yoke is not large, so that the power must be considerable. The pistons are not operated directly by a cylinder, as that would lead to irregular application of power, especially in a sea way. The pistons are controlled by collars or sleeves in which work endless screws. The cylinders operate gearing which turn the screws. This steadies the motion of the rudder in a sea way. It is claimed for the system that it gives great protection to the steering gear.

It may be said that this class of ships has not proved the success as seagoing vessels that was anticipated. The *Gota* in her return voyage from England experienced great trouble with her steering gear, which is open to the objection that any floating timber lodging between the yoke and the stern would jamb the whole mechanism. To this defect may be added the anchor stowage, the low search-light platforms, the forecastle rail—all of which combine to make the ship a poor sea boat. These defects are, however, not vital.

The changes to be made in these vessels are mainly in the battery, and further protection to the above-water torpedo tubes. The amount to be expended on the *Svea*, *Gota*, and *Thule* is about $1,376,000.

The complement of the *Svea* is 197, including 9 officers; that of the *Gota* 175.

DIMENSIONS AND COST.

Svea.—Length, 248.3 feet; beam, 48.56 feet; draught, 17.06 feet; displacement, 3,100 tons.

Gota.—Length, 258.5 feet; beam, 47.9 feet; draught, 16.73 feet; displacement, 3,200 tons.

Cost of each, $800,000.

ARMAMENT.

The original armament was as follows:

Svea.—Two 25-centimeter (9.8-inch), four 12-centimeter (4.7-inch), six 57-millimeter, eight machine guns. One fixed underwater torpedo tube.

Gota.—Two 25-centimeter (9.8-inch), six 15-centimeter (5.91-inch), five 57-millimeter, eight machine guns. One fixed underwater, two training abovewater torpedo tubes.

TACTICAL DATA.

Turning circle:

Name of vessel.	Speed.	Time.	Diameter.
	Knots.	*m. s.*	*Feet.*
Svea	6	7 50	1,246
	8	7 50	1,279
	10	5 48	1,345
Goat	8	7 37	1,338
	10	6 43	1,337

PROTECTION.

Hull protection: Water-line belt of 12 inches Creusot steel, diminishing to 6.5 inches at the ends.

Protective deck: 1.6 inches thick.

Turret: 9.61 inches thick in front, tapering to 7.97 inches in rear. Conning tower 8.79 inches thick.

MOTIVE POWER.

Engines: Horizontal compound, direct acting.

Diameter of cylinders:
Small, *Gota* 41.75 inches, *Svea* 44.75 inches.
Large, *Gota* 73.25 inches, *Svea* 77.75 inches.
Stroke, *Gota* 33.25 inches, *Svea* 31.19.

Boilers: Six of the admiralty type, made by the Motala Engine Company. Shell and furnaces made of iron.

Working pressure, *Svea* 75 pounds, *Gota* 90 pounds.
Total grate surface, *Svea* 381 square feet, *Gota* 327 square feet.
Heating surface, *Svea* 10,115 square feet, *Gota* 10,146 square feet.
I. H. P., forced draft, *Svea* 3,540, *Gota* 5,040.
I. H. P., natural draft, *Svea* 3,113, *Gota* 3,172.

Screws: Two 4-bladed, made of cast iron.

Coal capacity: Total, *Svea* 220 tons; *Gota* 245 tons.

Endurance: 1800 miles at 12 knots.

At her trials the *Svea* with forced draft made 14.67 knots, and with natural draft 14.25 knots.

THOR, NIORD.

DESCRIPTIVE AND EXPLANATORY REMARKS.

Battleships of the *Oden* type. Both ships were to be ready for service by the end of 1898, *Thor* to be fitted for flagship, and *Niord* to be fitted so as to be converted into flagship when required. The 9.8-inch gun on the *Thor* to be Canet; those on the *Niord* to be made at Bofor's works, in Sweden.

The *Thor* was built by the Bergsund Engine Company, Stockholm; keel laid October 26, 1896; launched March 7, 1898. The *Thor* was built wholly at these works, excepting the screws which were built at Finnboda.

The *Niord* was built by the Lindholmens Works, Gothenburg; her machinery at Motala, and her screws at Gothenburg; launched March 30, 1898.

Material of hull, steel; ram bow; two elliptical funnels, placed very close together; two masts, with two yards forward and one aft.

Dimensions.—Length, 278.2 feet; extreme breadth of beam, 48.56 feet; draught, 17.38 feet; displacement, 3,500 tons. Speed, 16.5 knots. I. H. P., 5,350.

ARMAMENT.

Two 25-centimeter (9.84-inch), one forward, one aft; arc of fire, 272 degrees.

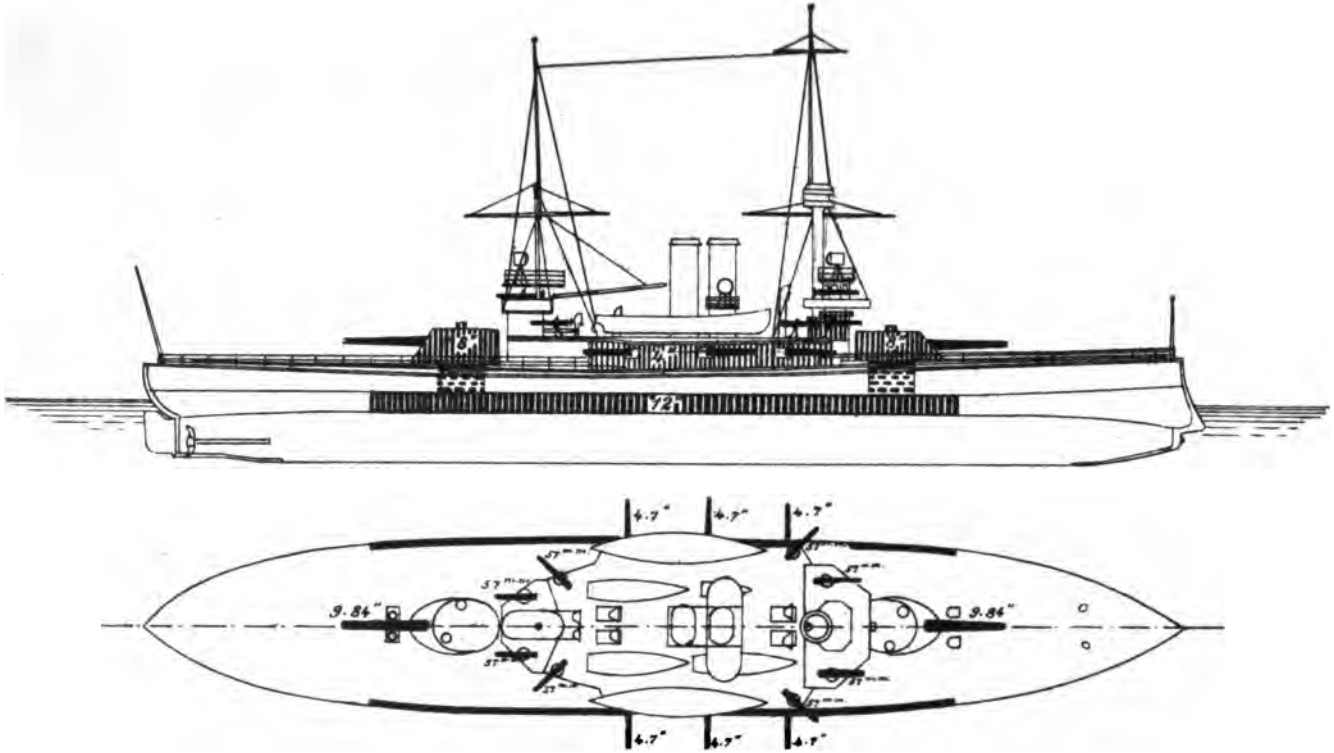
Six 12-centimeter (4.7-inch); arc of fire, middle gun 136 degrees, corner gun 115 degrees.

Ten 57-millimeter guns.

Four machine guns.

One underwater torpedo tube in the bow.

The 57-millimeter R. F. guns are distributed as follows: Two on the forward bridge, two on the after bridge, four at the forward end of the superstructure deck, two at the after end of the same. Two 8-millimeter machine guns in the tops, and two 25-millimeter double-barrel machine guns in the pinnaces.



THE NORRIS PETERS CO. PHOTO-LITHO. WASHINGTON, D. C.

Thor—Niord.
Swedish Battleship.
3500 Tons.

TACTICAL DATA.

Turning circle:

Name of vessel.	Speed.	Time.	Diameter.
	Knots.	*m. s.*	*Feet.*
Thor	6	9 50	1,213
	8	7 48	1,312
	10	6 6	1,345
	12	5 16	1,378

PROTECTION.

Hull protection: Partial steel belt of 12-inch harveyized steel. It is reported that the double bottoms of the *Thor* are designed with the idea of making her proof against an ordinary torpedo. These double bottoms are 5 feet in depth and extend all the way up to the protective deck. They are divided into compartments about 8 by 10 feet, and each compartment is water-tight and can only be entered by its own manhole plate. The boilers have around them coal bunkers 5 feet thick.

Protective deck: Two inches thick.

Turrets: Eight inches harveyized steel.

Casemates: Four inches; not harveyized. The casemate is made with the sides sloping inboard, so as to increase the arc of fire of the middle 12-centimeter gun. The length of the casemate is 154 feet, and inside there is a splinter bulkhead to protect in all directions against splinters.

MOTIVE POWER.

Engines: Of *Thor*, built by the Bergsund Works; those of *Niord*, by the Motala Engine Works.

Boilers: Six cylindrical single-ended boilers.

Electrical power is employed to an even greater extent on these ships than on the *Oden*. Besides the revolving turrets, each of the four ammunition hoists and two ventilator fans—one for the torpedo room and one for the dynamo room—are driven by electricity. There are in all 13 motors on board these ships (7 on board the *Oden*).

Screws, two; coal capacity, 300 tons; endurance, 2,000 miles.

THULE, ODEN.

DESCRIPTIVE AND EXPLANATORY REMARKS.

Coast-defense vessels, improvement on the *Gota* and *Svea*. *Thule* built at Finnboda, Sweden, the plates being made in 1891 at Bergsund and then sent to Finnboda; launched in 1893. *Oden* built at Stockholm; launched March 9, 1896.

Material of hull, steel; ram bow; two funnels, placed very close together; two masts, the forward one military, the after one light.

Dimensions of *Oden* same as of *Thor* and *Niord;* of *Thule* as follows: Length, 260.8 feet; extreme breadth of beam, 47.9 feet; draught, 16.73 feet; displacement, 3,300 tons.

ARMAMENT.

Thule.—Two 25-centimeter (9.8-inch), four 15-centimeter (5.91-inch) R. F., five 57-millimeter, eight machine guns. Two above-water torpedo tubes, training, for 17.75-inch torpedoes.

Oden.—Two 25-centimeter (9.8-inch), four 12-centimeter (4.7-inch), ten 57-millimeter, four machine guns. One fixed under-water tube for 17.75-inch torpedo.

TACTICAL DATA.

Turning circle:

Name of vessel.	Speed.	Time.	Diameter.
	Knots.	*M. S.*	*Feet.*
Thule	8 to 10	6 56	1,574
	6	8 12	1,509
Oden	8	6 12	1,574
	10	4 14	1,640

PROTECTION.

Hull protection: Complete water-line belt of Creusot steel, the thickness on the *Thule* varying between 9.61 inches and 6.49 inches. On the *Oden* the thickness is 7.97 inches.

The space between the outer armor and the inner side of the vessel is divided into cells, 50 on a side and 86 in the bottom, the ship being also divided into water-tight compartments.

Protective deck: There is a complete protective deck 1.6 inches thick.

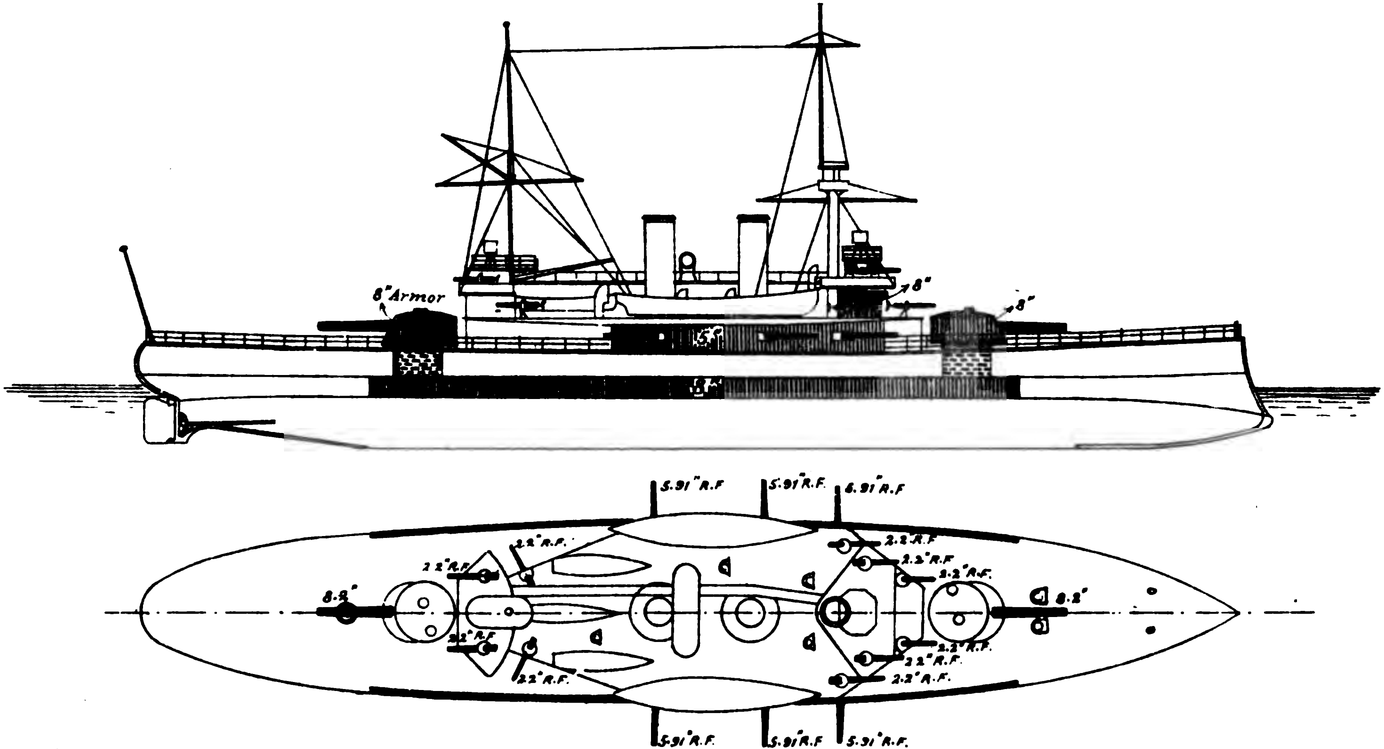
The turret on *Thule* is 9.61 inches in front and 6.49 inches in rear. On the *Oden* the thickness is 8.2 inches to 6.56 inches. Conning tower on *Thule*, 8.79 inches; on the *Oden*, 8.1 inches.

The heavy armor for the belt and turret of the *Thule* was supplied by Creusot; the other plates are Swedish make, from Domnarfolt.

The turrets for the heavy guns are turned by electric power. The ammunition hoists for these turrets are also actuated by electricity, while the ammunition hoists for the R. F. guns are driven by hydropneumatic power. The capstans and air-compressing pumps are likewise electric.

MOTIVE POWER.

Engines: *Thule*, two compound; total I. H. P., 3,200. *Oden*, two triple-expansion, each actuating its own propeller. Diameter of cylinders as follows: High pressure, 31.14 inches; intermediate, 47.2 inches; low, 75.5 inches; stroke, 27.27 inches; cooling surface of each condenser, 3,036 square feet. The power developed by both engines



THE NORRIS PETERS CO. PHOTO-LITHO., WASHINGTON, D. C.

Dristigheten
Swedish Battleship
3500 Tons.

under forced draft and with maximum speed is calculated to be 5,000 I. H. P.

Boilers: Six cylindrical, constructed for a pressure of 153 pounds per square inch, with a total heating surface of 9,817 square feet and a grate surface of 305.7 square feet. Besides the propelling engines there are on board the *Oden* 42 auxiliary engines, namely, 27 steam engines, 4 dynamos, 6 electric motors, 1 air-compressing pump, 2 hydropneumatic hoists, and 2 hydraulic pumps.

Two screws.

Trials of *Oden* were held at Stockholm May 25, 1897. Draught was shown to be 15 feet forward and 16.3 feet aft. In a trial trip of four hours and five minutes duration, under full steam, with natural draft, the engines developed 3,887.67 I. H. P. and a speed of 15.54 knots; steam pressure, 145 pounds; average revolutions, 109.8 per minute. Coal consumption, 1.63 pounds per hour per horsepower.

Trial trip of one hour and thirty-two minutes duration, under forced draft, 16.57 knots; 5,334 I. H. P.; steam pressure, 145 pounds; revolutions, 122.25 per minute. Coal consumption, 2.57 pounds per hour per I. H. P.

At the conclusion of the *Oden's* summer cruise, namely, September 25, 1897, she maintained, under forced draft, an average speed of 16.41 knots for two hours and twenty-eight minutes; the last forty minutes an average speed of 16.82 knots.

DRISTIGHETEN.

DESCRIPTIVE AND EXPLANATORY REMARKS.

An improved *Thor*, replacing the 10-inch guns of the latter by 8-inch and the 4.7-inch guns by 6-inch guns, all being Swedish guns made at Bofors. All armor also supplied by Bofors.

In order to decrease the rolling motion, the after part of the ship is to be considerably shortened, and bilge keels fitted.

The *Dristigheten* was laid down at the Lindholm Works, Gothenburg, in 1898. Material of hull, steel; ram bow; 2 funnels; 2 masts without military tops; 2 yards forward, 1 aft.

Dimensions.—Length, 285.5 feet; beam, 49.25 feet; draught, 16 feet (mean); displacement, 3,500 tons.

I. H. P., 5,000; speed, 16 knots.

ARMAMENT.

Two 21-centimeter (8.2-inch) guns, one forward and one aft in turrets; six 15-centimeter (5.91-inch) R. F., in a central battery amidships; ten 57-millimeter (2.2-inch) R. F.; 4 machine guns.

Two under-water torpedo tubes in broadside, for 45-centimeter (17.75-inch) torpedoes, said to be of the latest Elswick pattern.

The arrangements for conveying the ammunition to the heavy guns have been improved, inasmuch as the turret hoists carrying the ammunition from the magazines to the guns are equipped with two cars, one of which goes up while the other goes down. A considerable gain in time is thereby effected, which may be utilized toward increasing the rapidity of fire.

PROTECTION.

Hull protection: Partial water-line belt of nickel steel 8 inches thick, with 5.91-inch teak backing. From the orlop deck the ventilating trunks have disappeared and the vessel is equipped forward and aft with side ventilators.

Complete protective deck, 2 inches thick.

Turret armor 8 inches thick in front, tapering to 6 inches in rear. Casemates for the secondary battery are all 5-inch steel. Conning tower, 8 inches. The turrets have vertical friction rollers.

MOTIVE POWER.

Engines: Owing to the increased pressure carried it has been possible to reduce the size of the engine cylinders, which are as follows. High pressure, 28.51 inches; intermediate, 44.6 inches; low, 69.1 inches; total weight of propelling machinery, including water, is by requirement not to exceed 450 tons.

Boilers: Twelve Yarrow type, being built by the Motala Engine Works. The steam pressure is to be 209 pounds per square inch, while the older ships have 6 cylindrical boilers, with 153 pounds per square inch. The total heating surface is 14,210 square feet, the grate surface being 452 square feet.

Screws: Two.

Total coal capacity: 300 tons, against 282 in the *Oden*.

"A," "B," "C."

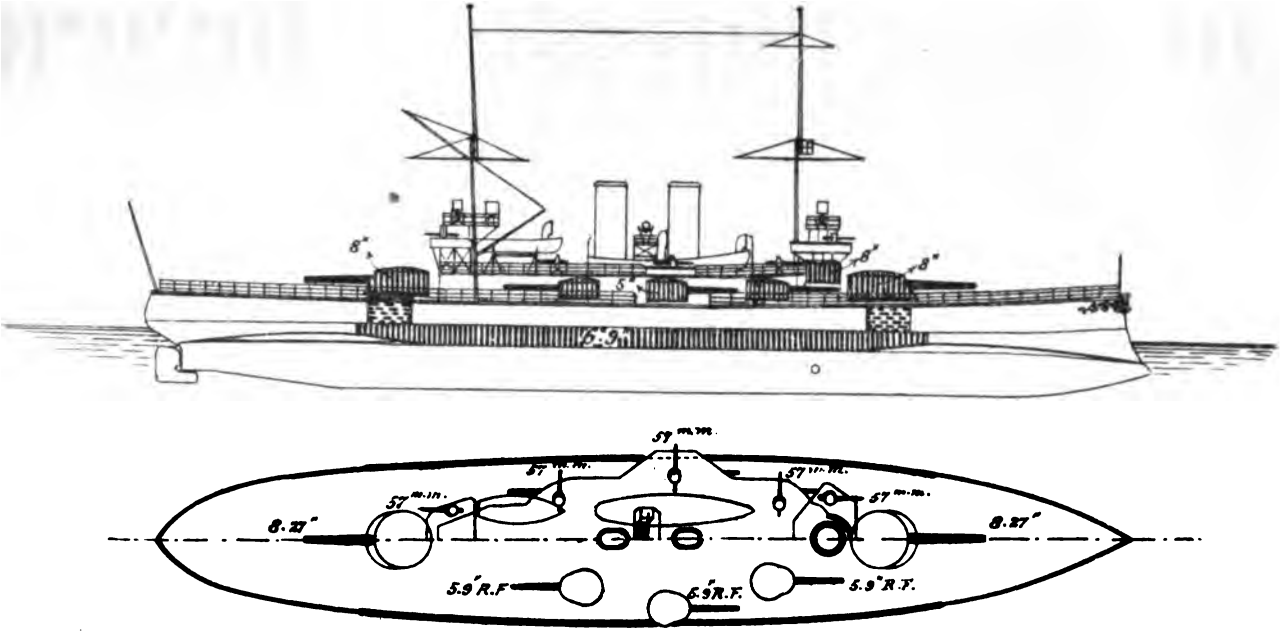
DESCRIPTIVE AND EXPLANATORY REMARKS.

Battleships of the second class, contracts signed October, 1899. All three ships to be ready for launching eighteen months after the signing of the contract; "A" and "B" to be delivered in twenty-six and "C" in twenty-four months. "A" building at the Kockum works at Malmo, "B" at the Bergsund works at Stockholm, and "C" at the Motala-Lindholm works at Gotaborg.

Material of hull, steel; ram bow; two funnels; two masts with signal yards on each; no fighting tops. Speed, 16.5 knots at natural draft. Cost of construction: "A," $717,972; "B," $723,064; "C," $618,816. Total cost: "A," $1,206,000; "B," $1,206,000; "C," $1,206,000.

Armament.—Two 8.27-inch; six 5.91-inch R. F.; ten 57-millimeter R. F.; two 37-millimeter R. F. Two submerged torpedo tubes.

Four 35.4-inch searchlights.



A, B, and C.
Swedish Battleships.
3650 Tons.

THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C

PROTECTION.

Hull protection: There is an armored citadel 165 feet long, the armor on which is 175 millimeters (6.89 inches) thick. All armor is of the Krupp process.

Complete protective deck, 1.89 inches thick.

Turrets, 7.87 inches thick; casemates, 5.55 inches; conning tower, 7.87 inches.

MOTIVE POWER.

Engines: Two engines in separate compartments. Medium steam pressure, 14.7 kilograms per square centimeter (209 pounds per square inch); 5,500 I. H. P. Speed of 16.5 knots to be obtained with natural draft, as stated above, in which case the coal consumption is not to exceed 0.85 kilogram (1.87 pounds) per hour per I. H. P. Total weight of machinery for propelling ship, including screws, shafts, boilers, pumps, etc., is not to exceed 947,978 pounds.

Boilers: Eight Yarrow type. Total heating surface, 15,610 square feet; grate surface, 376.8 square feet.

Steam steering gear. Balance rudder, adapted to be operated from the bridge, from the armored conning tower, and also from a station below the latter. Under full steam, the time required for putting the rudder from hard astarboard to hard aport, and vice versa, is not to exceed twenty seconds. Hand steering gear is also provided.

Electric installation: Three generators, one of 200 ampères for interior lighting (281 incandescent lights), one of 400 ampères for searchlights (four of 35.4-inches; contracts provide for same installation as on older battleships, subject to change), and one of 500 ampères for motors.

NORWAY.

HARALD HAARFAGRE, TORDENSKJOLD.

DESCRIPTIVE AND EXPLANATORY REMARKS.

Coast-defense battleships. Striking resemblance to *Libertad* and *Independencia* of the Argentine navy, and predominant idea seems to have been a miniature edition of *Royal Sovereign* or *Barfleur*, in the English navy. Ships painted black, with yellow funnels and gun shields. Fighting tops and upper works white.

Harald Haarfagre launched January 4, 1897, *Tordenskjold* March 18, 1897; both built by Armstrong Company, Elswick; keels laid down in 1896.

Material of hull; steel, sheathed and coppered; ram bow; one funnel; two military masts, two tops on each (one for searchlight); six boats carried, two of which are wooden vedette boats.

DIMENSIONS.

Length between perpendiculars, 280 feet; on load water line, 274 feet 6 inches; extreme breadth of beam, 48 feet 6 inches; mean draught, 17 feet 6 inches; displacement, 3,403 tons.

Cost (estimated), about $925,000.

I. H. P. (natural draft), 3,700; speed (corresponding), 15 knots; estimated I. H. P., 4,500; speed, 16 knots with forced draft.

ARMAMENT.

Two 8.27-inch guns installed in separate armored turrets in barbettes forward and aft. Their arc of fire is about 270 degrees.

Six 4.7-inch R. F. guns installed on the upper deck between the two turrets, three on each side, protected by shields. Two of these fire ahead, two astern, and all abeam.

Six 76-millimeter (12-pounder) R. F. guns, two on the forward bridge, two on the after bridge, and two immediately forward of the after 4.7-inch guns.

Six 37-millimeter R. F. guns, two immediately aft of the forward 4.7-inch guns, and two in each lower military top.

Two 18-inch submerged torpedo tubes, one on each broadside. They are at right angles to the ship's longitudinal axis, and can not be turned.

Three searchlights, one in the upper top aft and two on the forward bridge.

PROTECTION.

Hull: Belt for about 170 feet of the length of the ship, Harveyized steel; maximum thickness 7 inches, minimum 4 inches; width, 6 feet 6 inches; terminated at the barbettes fore and aft by bulkheads of same thickness. Coal bunkers, part below, part above, protective deck.

Protective deck: Sloping deck of 2-inch steel from end to end.

Barbettes fore and aft, on upper deck, 6-inch steel, extending down to protective deck. Armored ammunition hoists. Conning tower of 6-inch armor plate. Shields for the 4.7-inch guns are curved and 3.74 inches thick. Revolving turrets for the 8.27-inch guns have 8 inches of armor in front and 5 inches at the sides and rear.

MOTIVE POWER.

Engines: Two sets triple expansion. Diameter of high-pressure cylinder, 23.98 inches; intermediate, 35.51 inches; low, 53.9 inches; stroke, 17.99 inches.

Boilers: One single-ended and two double-ended, having a common smokestack.

Twin screws.

Coal capacity at load water line, 200 tons; total capacity, 400 tons, 250 of which lies above protective deck.

TRIAL TRIPS.

The official trial trips of the *Harald Haarfagre* took place in June, 1897. The contract provided that the engines, with a steam pressure of 10.9 kilograms per square centimeter (154.78 pounds per square inch) and 160 revolutions per minute, were to develop at least 4,500 I. H. P. and give the ship a speed of at least 16 knots. It appears that at the trial trip referred to (of six hours' duration) the engines developed an average of 4,500 I. H. P. with natural draft, giving the ship, loaded to 3,500 tons, an average speed of 17.15 knots. It may seem remarkable that such high results were attained with natural draft only, but in all probability Armstrong in this case adopted the same principle which, in accordance with official regulations, prevails in the English navy, where natural draft for ships of the size of the one in question means half an inch air pressure. At the trials of the *Oden* the forced draft varied between 5 and 12 centimeters; that is to say, it was less than half an inch.

NORGE, EIDSVOLD.

DESCRIPTIVE AND EXPLANATORY REMARKS.

Coast-defense battleships, closely resembling *Harald Haarfagre*, but somewhat heavier. Building by the Armstrong Company at Elswick. *Norge* launched March 31, 1900. *Eidsvold* launched June 14, 1900. Material of hull, steel; ram bow.

Dimensions.—Length, 290 feet; extreme breadth of beam, 50 feet 6 inches; draught, 16 feet 6 inches; displacement, 3,850 tons.

Guaranteed speed, 16.5 knots with 4,500 I. H. P.

ARMAMENT.

Two 8.27-inch guns, forward and aft, in revolving turret shields. Caliber, 44. Arc of fire, 270 degrees.

Six 5.9-inch R. F. 46-caliber guns, not adapted for use of cartridge cases. Four of these are in casemates, two forward and two aft, giving them a train from right ahead and astern to 30 degrees aft and forward of the beam, respectively, and two between these behind armored shields train from 60 degrees forward of to 60 degrees abaft the beam.

Eight 12-pounders, caliber 40, installed two in each broadside between the 5.9-inch guns and the remaining four over the casemates.

Six 3-pounders, two placed in each of the fighting tops and the remaining two on the forward bridge.

Two 18-inch submerged torpedo tubes.

PROTECTION.

Hull protection: Harveyized belt, 6 inches thick, 6 feet 6 inches wide, extending along citadel and connected forward and aft by vertical bulkheads of same thickness.

The use of wood is to be avoided wherever possible.

Thickness of protective deck, 2 inches.

Barbettes of nickel steel 6 inches thick.

Casemates, four in number, 5 inches thick.

Conning tower, 6 inches.

Turrets—front, 8.86 inches; sides and rear, 5 inches.

Shields of two other 5.9-inch guns, 6 inches thick.

(A Norwegian magazine article states that the whole armor is made of ordinary nickel steel, with the exception of the citadel armor, which is of the Krupp type.)

Motive power.—Engines: Two vertical triple-expansion. Boilers: Yarrow. Screws: Two.

Coal capacity at load water line, 250 tons; total capacity, 400 tons.

HOLLAND.

EVERTSEN, KORTENAER, PIET HEIN.

DESCRIPTIVE AND EXPLANATORY REMARKS.

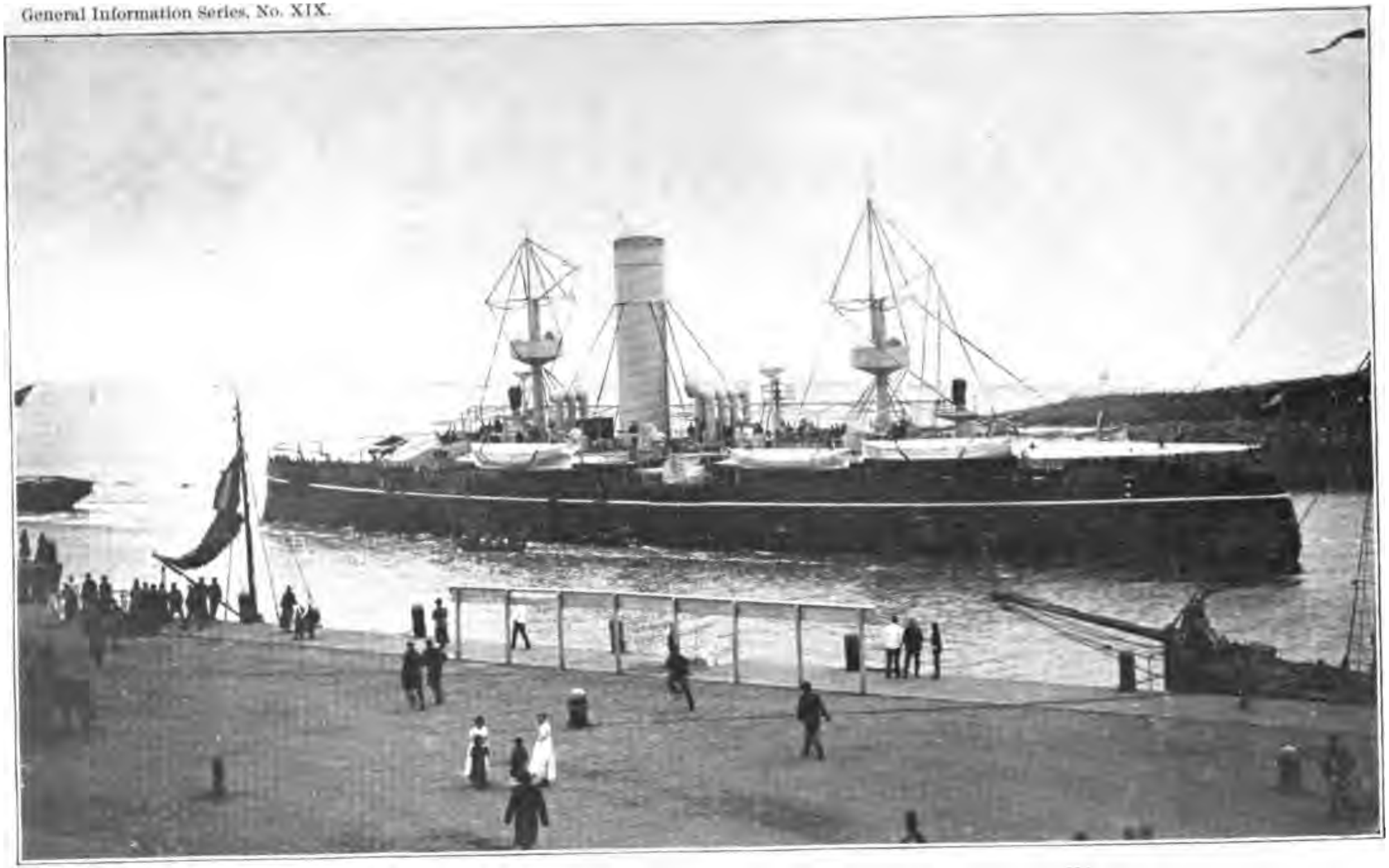
These coast-defense ironclads were laid down in 1893, the *Evertsen* at Flushing, the *Kortenaer* at Amsterdam, and the *Piet Hein* at Fijenoord; the first was launched September 30, 1894, the second October 27, and the third August 16 of the same year.

They are built of steel, not sheathed; ram bow, very blunt; one funnel each; two military masts, one oval top on each; have a complement of 267; can carry about ten to thirteen weeks' provisions and water for fourteen days.

The vessels are intended, should occasion arise, to operate in the East Indies, and the greatest draught that can enter Surabaya, the chief Dutch repair arsenal in the Indies, is 18 feet. This light draught entails great breadth of beam to insure the proper carrying capacity. Secondly, they are built very full forward and comparatively fine aft, so that the draught is nearly the same forward and aft; and this is because in the home waters they are intended to fight bows on, and the fullness forward was necessary to support the weight of the two heavy bow guns and their protection. Finally, after sacrificing the ship's speed to the conditions imposed, there is very little carrying capacity, and it is said, to be doubtful if they ever leave Holland.

The vessels might, with advantage, have a fuller under-water afterbody, which would have permitted better protection to the after-body and at the same time have given a better angle to the propeller shafts. As it is the shafts meet a very little distance forward of the turning center, and the ships' turning powers are very poor; and tactical power in the dangerous waters about the Helder is a necessity.

The quarters for officers have good natural ventilation and plenty of light, but are very small. The crew space seems ample. Because the



PIET HEIN. (Holland, coast defense ship.) 3,520 tons; I. H. P., 4,735; speed, 16 knots; launched, 1894.

vessels were intended for service in the tropics the men's closets are all on the main deck; for the same reason they are built of wood instead of iron. When the question arose of the substitution of some less inflammable material than wood for interior fittings, these ships were well on toward completion, and it was not deemed advisable to make any alterations; consequently, the decks above the protective deck (also the platforms) are everywhere wood-sheathed; and the bulkheads, cabin and mess-room furniture, the men's mess tables and chests, etc., are likewise wood.

The boats carried are as follows: Sailing launch, rig, 2 split-lug sails; steam launch, carries no sail; two cutters, rig, 1 split lug; 2 whaleboats, 1 of which is fitted inside throughout the length of the boat with air reservoirs, rig, 1 split lug; 1 dinghy, rig, 1 spritsail. These are the regulation rigs for boats of the respective classes. Commanding officers sometimes cause their gigs to be fitted with sliding gunters, but this is contrary to regulation. These boats seem to be very substantially built; they are not fitted with torpedoes.

Dimensions.—Length over all, 282 feet 9 inches; between perpendiculars, 267 feet 8 inches; extreme breadth of beam, 46 feet 11 inches; maximum draught, 17 feet 2 inches; mean draught, 16 feet 9 inches; displacement, 3,520 tons.

Cost, $1,065,148; weight of hull, 1,490 tons; I. H. P., 4,735; maximum speed, 16 knots.

ARMAMENT.

Three 8.27-inch (21-centimeter) Krupp 35-caliber guns.

Two 5.91-inch (15-centimeter) Krupp R. F. 40-caliber guns.

Six 2.95-inch (75-millimeter) guns.

Eight 1.46-inch (37-millimeter) guns.

Three torpedo tubes, above water on berth deck. Two in broadside train 45 degrees each side of beam; stern tube fixed.

MAIN BATTERY.

Two of the 8.27-inch guns are placed in a pear-shaped barbette forward, protected by a hooded shield, and train through 280 degrees, and one aft trains through 240 degrees. The height of the trunnion axis of the two forward guns, measured from the water line, is 18.4 feet; of the after gun, 16.4 feet.

In both the forward and after barbette the turntable is supported on a ring of live steel balls and trains around a central pivot. The after turntable is trained by hand only; the forward one by hydraulic or hand power, at will. The hydraulic pumps are driven from the shaft of the capstan engine, located on the platform underneath the protective deck and just forward of the capstan spindle. The other operations at the gun, loading and elevating, are done by hand, although for purposes of drill there is a hydraulic hand pump at the side of the gun for "pumping in" the carriage on the slide. Although the guns can be elevated through 25 degrees they are never fired at anything beyond 13 degrees.

Trials: Thirteen degrees was the maximum angle at which the barbette guns were fired on the official trial of the *Kortenaer*, and the result of the round from the after gun was to bend the left-hand slide bracket—not perceptibly to the eye, but sufficiently to prevent the gun from being pumped in on the slide. These trials were made with full-weight charge and projectile, viz., charge, 119 pounds P. B. No. 2; projectile, A. P. and common, 308.6 pounds. The initial velocity of both projectiles is 1,903 foot-seconds. The range tables for A. P. shell are computed to 3,281 yards only, at which range the remaining velocity is 1,440 foot-seconds. For the common shell at the same range the remaining velocity is 1,424 foot-seconds.

The two 5.91-inch guns, with shields, are placed one on each broadside in sponsons, and train from right ahead through 180 degrees. These sponsons are at the height of the main deck, and elliptical in shape. During the battery trials these guns were fired directly ahead and directly astern with full-service charges of smokeless powder and 112-pound projectile. When firing ahead the flying bridge is unshipped. The guns were also fired at an angle of elevation of 13 degrees with full-weight charge and projectile. The performance of the gun and carriage was said to be in every way satisfactory.

No night sights are fitted to any of the guns.

Ammunition and hoists: It was originally designed that all ammunition should be hoisted by hand. This was later changed, and the after 8.27-inch and the 5.91-inch supply are furnished by hydraulic power. The after 8.27-inch ammunition tube is very conveniently situated, but that for the 5.91-inch guns, just abaft the mainmast, is 40 to 50 feet away from the breech of the guns, and the cartridge has to be carried this distance over a deck wholly unprotected from the enemy's fire. The ammunition for the two forward barbette guns is hoisted by hand.

SECONDARY BATTERY.

Two of the 2.95-inch Krupp guns, on the bridge deck, can train from aft to about 45 degrees forward of the beam; two from ahead to about 45 degrees abaft the beam, although at the latter train it would seem that the discharge might interfere with the service of the 5.91-inch guns. The guns can be depressed to an angle of 10 degrees. They use fixed ammunition, smokeless-powder charge, and common and A. P. shell of 12.9 pounds weight.

The ammunition is supplied through the military masts. These are oval in section, and each is divided into two unequal parts by a vertical iron lattice-work partition. Through the smaller division thus made the 2.95-inch cartridges are hoisted by means of a chain passing over two sprocket wheels, operated by a crank. The base of the cartridge rests on a bracket secured to the endless chain and is held secure by a clamp spring. The brackets are spaced about one and one-half times the length of the cartridge apart. There is a hinged door on the mast just above the bridge deck, through which the charges are removed.

The other division of the mast affords a passage for the 37-millimeter ammunition, which is hoisted into the tops in boxes of 12 each by means of a single whip, worked by the men in the top. The supply for the 37-millimeter guns on the bridge deck is removed through the same door that answers for the 75-millimeter (2.95-inch) guns.

There are six of these 37-millimeter guns, two in each top and two in broadside on the bridge deck and nearly abreast the smoke pipe. They are R. F. guns, made of bronze, about 20 calibers in length, and manufactured in Amsterdam. They have no distinctive name or mark. The breech action resembles that of the Hotchkiss gun. The ammunition is the same as that supplied to the Hotchkiss 37-millimeter revolving cannon.

These guns are all on pedestal mounts. The crews of those on the bridge deck are sheltered by a fixed shield 0.59 inch thick and about 4.1 feet in height, and further by a shield that revolves with the gun and is about 0.18 inch thick.

The military tops are of ordinary skin plate, 0.28 or 0.31 of an inch in thickness.

Six 17.72-inch Whitehead topedoes are carried. The only storeroom is located under the protective deck, just forward of the tiller room. There are no arrangements for planting ships' mines. The torpedo tubes are of bronze, fitted for both air and powder discharge. The officer in the forward conning tower can fire either broadside torpedo, or both at once, and the after torpedo may be fired from the after tower. There is no net defense against torpedo attack.

Two Schuckert 21.62-inch searchlights, one on each conning tower. These admit of both train and elevation. The dynamos are located on the port side, below the protective deck, in a compartment between the engine-room bulkhead and the port after boiler. They are two in number, Siemens-Halske manufacture; output, 80 volts and 100 ampères.

The highest top is 41 feet above the load water line; the funnel, which rises about halfway up the topmast, about 65 feet.

TACTICAL DATA.

Turning circle:

Helm.	Revolutions.	Time for 180°.		Diameter.	
		m.	*s.*	*Yds.*	*ft.*
22° port	150	2	0	579	1
22° starboard	150	2	10	634	0
22° port	91	2	52	601	1
22° starboard	91	2	42	557	2
35° starboard	[1]90	2	55	([2])	

[1] Starboard engine only.

[2] Complete circle in 3 minutes 15 seconds.

PROTECTION.

Hull protection: nickel-steel armor, 3.25 per cent steel. Belt 5.91 inches thick for about 150 feet in central part, then 3.94 inches thick to ends of ship. This belt extends 3 feet 3 inches below and 2 feet above the load water line; it is backed with teak of about the same thickness. Above protective deck at angle of 45 degrees and on all sides of engine and boiler rooms is a glacis about 3 feet wide and 6 inches thick. Cofferdams above protective deck at sides of engine-room space. Coal both sides of boilers as high up as berth deck; below protective deck the maximum thickness of this protection is about 7.5 feet. The ships are provided with water-tight bulkheads. Below the protective deck the water-tight bulkhead doors are operated by means of a handwheel, bevels, pinion on a shaft, and racks on the laterally sliding door. The shaft is carried up through the protective, orlop, and berth decks, whence each separate door can be closed by means of a hand lever. There is communication through these doors between the two engine rooms, between engine rooms and after boiler compartment, and between the two boiler compartments.

Protective deck, 1.97 inches thick, extends entire length of ship, laid in two courses.

The pear-shaped barbette inclosing the two forward 8.27-inch guns, their turntable, and the opening of the ammunition hoist, has armor 9.45 inches thick, backed with teak of about the same thickness.

Conning towers: forward, 9.45-inch armor; after, 1.25-inch armor, backed with teak; top of former, 4 inches thick; lifts by means of screws, and there are no peepholes in the walls. Communication tube from conning tower to protective deck, with 8-inch armor.

Ammunition tubes: two for 8.27-inch guns and one for 5.91-inch guns, with armor 4 inches thick.

Shields: for 8.27-inch guns, 1.18 inches thick; for 5.91-inch and 2.95-inch guns, 0.47 inch thick.

MOTIVE POWER.

Engines: Two vertical triple-expansion three-cylinder type; diameter of cylinders, 26.97, 40.03, 63.04 inches; stroke, 27.03 inches.

Boilers: Four simple boilers placed in two compartments. One auxiliary boiler. Forced draft on Howden system, with air-heating tubes arranged horizontally and in two nests.

Screws: Two.

Coal capacity: At load water line, 277 tons; total capacity, 330 tons. Endurance at 14.5 knots speed, 1,350 miles; at 9 knots, 2,800 miles.

TRIAL TRIPS.

With forced draft, October 24, 1895, the *Kortenaer* held a four hours' trial; 149.35 revolutions; I. H. P., 4,436; coal consumption, 1.72 pounds; speed, 15.78 knots; with 150.55 revolutions, coal consumption 1,716 pounds, 4,658 I. H. P. was attained; speed not taken. With natural draft, October 3, 1895, full power, four hours' duration, 131.7 revolutions; I. H. P., 3,435; coal consumption, 1.65 pounds; speed, 14.44 knots.

Piet Hein, in October 1895, with 133.27 revolutions, I. H. P. 2,787, coal consumption 1.83, natural draft, made a speed of 13.78 knots. October 24, 1895, in four hours, with 149.5 revolutions, I. H. P. 4,736, coal consumption 2.02 pounds, made a speed of 16.118 knots, forced draft.

Evertsen, natural draft, 114.9 revolutions, I. H. P., 1,886, coal consumption, 2.02, speed, 12.425 knots; forced draft, 153 revolutions, I. H. P., 4,735, coal consumption, 2.64 pounds, speed, 15.85 knots.

KONINGIN REGENTES.

DESCRIPTIVE AND EXPLANATORY REMARKS.

A second-class battleship, an enlarged and improved *Evertsen*, to be built of steel, equipped with a ram, armor belt, protective deck, battle gratings above the engines and boilers, and armored conning towers. Building at the Government yard at Amsterdam. One very high funnel placed close abaft foremast; two masts without military tops.

Dimensions.—Length, 317 feet; beam, 50 feet; draught, 18 feet 10 inches; displacement, 4,950 tons, with 650 tons of coal.

Speed with 400 tons of coal on board, draught 18 feet, is to be 16 knots. I. H. P. is to be 6,000.

ARMAMENT.

Two 24-centimeter (9.45-inch) R. F. guns in barbette turrets, with armor protection of 7.87, 5.12, 3.94, and 1.97 inches thickness, varying from front to rear.

Four 5.91-inch R.F., with nickel-steel shields 3.94, 1.97, and 0.98 inches thick.

Eight 2.95-inch R. F. guns, with nickel-steel shields 2.95, 1.98, and 0.98 inches thick.

Four 37-millimeter guns with steel shields. One above water bow torpedo tube, and two submerged broadside tubes.

PROTECTION.

The armor belt extends the whole length of the ship, and is 6.23 feet high; with 650 tons of coal on board and full equipment, 4.26 feet of the belt is below the water line. The thickness of the belt amidships for a space of 190.2 feet is 5.91 inches, tapering to 3.94 inches. The thickness of the protective deck is 1.98 inches.

The barbette turrets are 9.84 inches thick; the turret walls to the protective deck, 7.09 inches.

The battle gratings above the engine and boiler rooms are 27.56 inches high and 5.91 inches thick.

The ammunition hoists for the 5.91-inch and 2.95-inch guns are protected by 3.94 inches of armor.

All armor is to be Krupp face-hardened nickel steel.

MOTIVE POWER.

Two vertical triple-expansion engines, with copper surface condensers, the engines to be separated from each other by longitudinal bulkheads. The requirements are that the engines shall be able to develop for four consecutive hours 6,000 I. H. P., while the atmospheric pressure under the grates shall not exceed that exerted by a water column of 0.98-inch.

Six Yarrow boilers, to be placed in two groups in two separate boiler rooms, with stokeholds fore and aft. The boilers are designed to have a working pressure of 250 pounds per square inch.

Ventilation.—Besides the natural ventilation by means of air pipes, two fans (Sturtevant type) will be installed, with the necessary piping and automatically closing valves, for cooling the air above the protective deck, and two fans for ventilating the lower part of the ship. The plans also provide for an ice machine, with the necessary piping, to maintain a low temperature in the ammunition rooms and also for the purpose of producing ice and cooling the drinking water.

Electric lighting.—The ship is to be lighted by electricity and to have two search lights.

The conveying of the ammunition to the guns shall be effected by both electric and hydraulic power, and also by hand.

Water-tight divisions.—The ship is divided into 340 water-tight compartments, 170 of which are between the protective deck and 'tweendecks, and 170 in the double bottom. Over the whole length of the double bottom—which extends from frame 20 to frame 118—the compartments are so arranged that they can receive salt water as ballast, with the exception of the four central compartments between frames 48 and 68, which are intended for boiler feed water.

Wooden decks.—The orlop deck, main deck, and forecastle are covered with wood. In the 'tweendecks and upper deck under the forecastle the steel is not covered with wood.

Auxiliary steering station.—In the forward shell room a water-tight space is provided as an auxiliary steering station and equipped with the necessary telegraphs, etc.

Wall covering and wainscoting.—The wall covering, wainscoting, and as far as possible also the furniture above the protective deck are to be of steel.

DENMARK.

HERLUF TROLLE, "A".

The second-class battleship *Herluf Trolle* was laid down at the dockyard at Copenhagen in 1896 and launched September 2, 1899. "A," a second vessel of the same type, but of somewhat greater power and speed, is to be laid down.

Material of hull, steel; complement, 250 men.

Dimensions.—Length, 271.9 feet between perpendiculars; beam, 49.5 feet, maximum at water line; draught, 15.97 feet, mean load, on an even keel; displacement, 3,470 tons.

Speed, 15 knots; I. H. P., 4,200.

ARMAMENT.

Two 9.45-inch R. F. guns in separate revolving turrets; four 5.91-inch R. F. guns installed separately in the angles of the casemate; eight 37 millimeter guns placed at different parts of the deck and on top of the casemate, protected only by the shields on the mounts: two 8-millimeter Maxims.

One fixed bow torpedo tube below the ram; two broadside training tubes, also below the water line.

PROTECTION.

The vertical side armor extends from aft forward over a length of 261.4 feet, and is 7.02 feet wide and from 6.89 inches to 7.87 inches thick, extending 3.61 feet below the water line. Forward of this armor is a vertical bulkhead of 6.89 inches thickness.

Double bottoms and numerous water-tight compartments.

The protective deck, which extends over the whole length of the ship, is 3.44 feet above the water line and is 2.24 inches thick. On this deck are located the lower stationary parts of the two turrets, one forward and the other aft, and between them a casemate which does not extend to the ship's side. Forward of the forward turret is a forecastle.

The armor of the barbettes is 6.89 inches thick; that of the revolving turrets 6.89 inches in front and 5.91 inches in the rear.

The casemate armor is 5.91 inches thick around the 5.91-inch guns, and 2.56 inches in other parts.

The conning tower is placed above the casemate, and near its forward edge, and has 7.87 inches of armor with a 1.1-inch skin.

The side armor, turret, and conning-tower armor are of chrome-nickel steel.

Motive power.—Two triple-expansion engines, to develop 4,200 I. H. P. and a speed of 15 knots.

BRAZIL.

MARESCIALLO DEODORO, MARESCIALLO FLORIANO.

DESCRIPTIVE AND EXPLANATORY REMARKS.

Battleships for harbor defense. Objects sought in their construction were to secure effective armament, protection, and coal capacity, while at the same time providing for such light draught that the vessels could ascend the large Brazilian rivers.

Both ships built by the Forges et Chantiers de La Seyne in France, the *Maresciallo Deodoro* being laid down in December, 1896, and launched June 18, 1898; the *Maresciallo Floriano* laid down in March, 1897, and launched in 1899.

Material of hull, steel; ram bow; one funnel; two masts, each with one fighting top; complement, about 200; to carry forty-nine days' provisions and water for fifteen days; weight of hull, 1,027 tons; I. H. P., natural draft, 3,400; speed, 15 knots.

Dimensions.—Length, 267 feet 6 inches; beam, 47 feet 3 inches; maximum draught, 13 feet 2 inches; displacement, 3,162 tons.

ARMAMENT.

Two 9.4-inch B. L. Armstrong 40-caliber guns in closed turrets.

Four 4.7-inch R. F. 50-caliber guns in casemates on main deck.

Two 6-inch howitzers, B. L., at extremities of superstructure.

Four 57-millimeter R. F. guns on superstructure above casemates.

Two 37-millimeter R. F. guns on forward bridge.

Two 25-millimeter machine guns on bulwarks of superstructure.

Two 75-millimeter guns, with field carriages.

Two machine guns in the fighting tops.

All the above guns furnished by the Armstrong Company, Elswick.

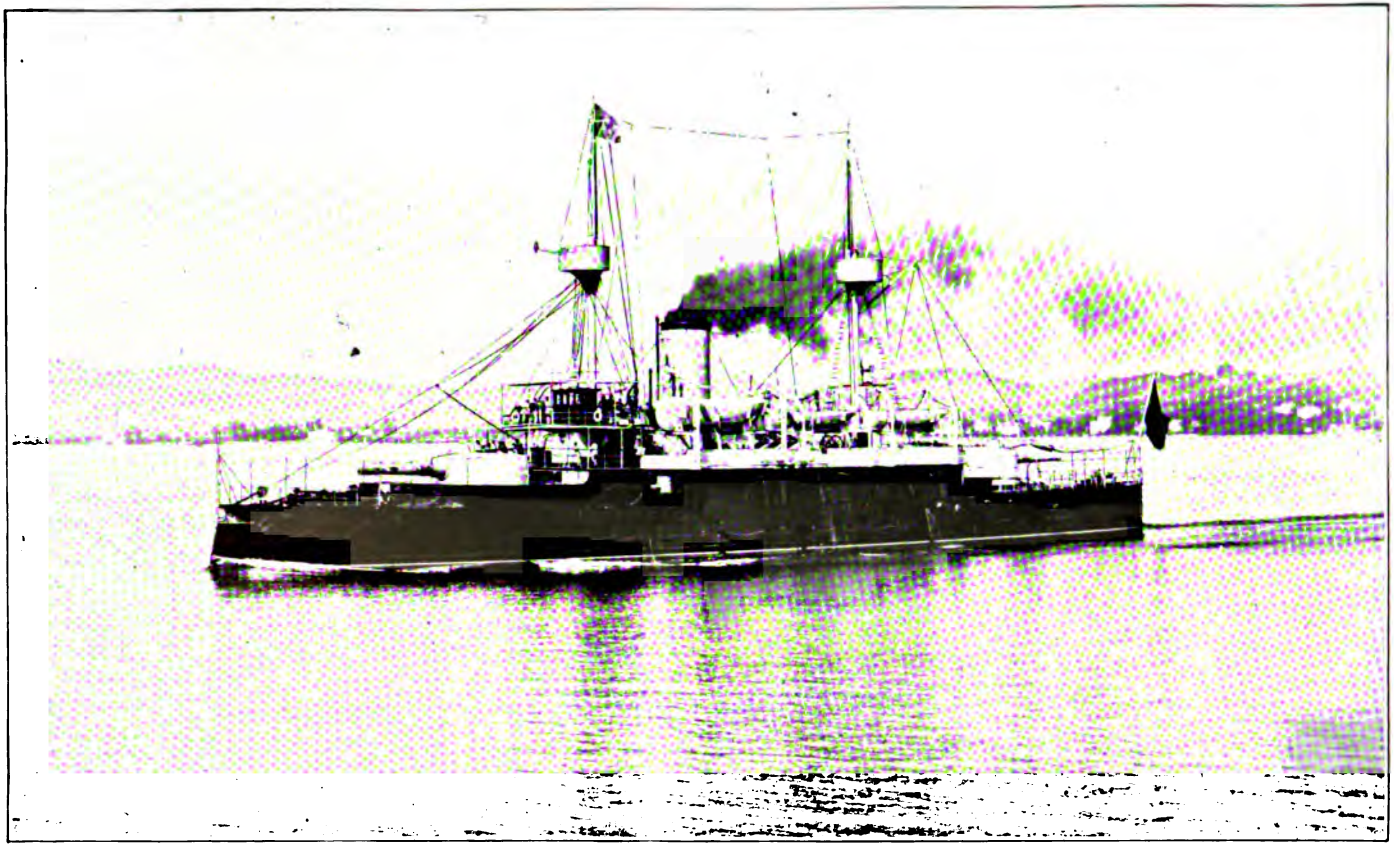
Two submerged tubes, slightly abaft forward turret, set at angle of 45 degrees forward of beam. Weight of torpedo outfit, furnished by Armstrong, 30.2 tons.

Two search lights, one above pilot house and one on platform on the after mast.

The weight of the battery and ammunition, ordnance stores and accessories, and dynamos is 323 tons. The weight of the torpedo outfit is 30.2 tons.

The ammunition supply is as follows: 9.4-inch guns, 80 rounds each; 4.7-inch guns, 150 rounds each; 57-millimeter (6-pounder), 400 rounds each; 37-millimeter, 500 rounds each; 25-millimeter, machine, 500 rounds each; 6-inch mortars, 60 rounds each; 75-millimeter (12-pounder), 300 rounds each.

Turrets and their ammunition hoists operated by electric machinery interchangeable with hand power. The electric machinery turns the turret through 250 degrees in sixty to seventy seconds. The turrets



MARESCIALLO DEODORO. (Brazil, coast defense ship.) 3,162 tons; I. H. P., 3,400; speed, 15 knots; launched, 1898.

are balanced, of the type installed in the *Jauréguiberry*. The ammunition hoist delivers its load at the side of the gun opposite that to which the breach is opened.. The hoist must raise the complete charge in forty seconds (about 0.2-meter per second) or the powder charge alone in twenty seconds. Provision is made for storing 20 projectiles in the turret.

The hoists (electric) for the 4.7-inch R. F. guns are alternating in motion. Two cages, each carrying 3 rounds, are provided for each casemate; one rises as the other descends.

The hoists for the mortars and small R. F. guns are all operated by hand power.

The 9.4-inch guns are placed in two closed turrets forward and aft on the midship line, above the main deck. Each trains through an arc of 250 degrees.

The 4.7-inch guns are carried in four separate armored casemates situated on the main deck, two abaft the forward turret, and two forward of the after turret, on the sides of the ship, and train through 110 degrees. Their shields are circular, masking the ports, and carried on the guns themselves. These guns are operated exclusively by hand.

The 57-millimeter guns are carried at the corners of the superstructure, resting on top of the casemate armor of the 4.7-inch guns below them. The ammunition is hoisted by means of a hand windlass, 6 or 8 rounds being placed in a cage.

Electric installation.—Four Sautter-Harlé dynamos, each of 400 ampères and 80 volts, supply electricity for turret machinery, ammunition hoists, projectors, lamps, etc. Three dynamos are sufficient to do all this work, the fourth remaining in reserve. Any one machine is capable of supplying all the incandescent lamps and the ventilators outside of engine and fire rooms. The number of lamps provided is: Two hundred of 10 candlepower, 4 of 50 candlepower, 7 of 30 candlepower, and 2 projectors of 23.6 inches diameter.

PROTECTION.

Hull protection: belt, 5 feet 6 inches in depth amidships, the thickness varying from 13.78 to 5.91 inches, tapering to 7.09 inches forward and 5.91 inches aft; thickness at the lower edge amidships, 5.91 inches, tapering to 3.94 inches at stem and stern. The belt is 2.3 feet above and 3.28 feet below the water line. It is laid on a wood backing and fastened to 0.354-inch + 0.354-inch steel plating. Cofferdam above protective deck, 3.93 feet high, 3.28 feet wide. Main deck beneath superstructure has steel-plated bulkheads at each end.

Protective deck: 1.38 inches thick, extends across vessel and joins upper edges of belt. All openings protected by coamings 3.94 inches thick. The deck is formed of two layers of mild steel, and its thickness diminishes at the ends of the ship to 0.98 inch.

The barbette armor, including that of the ammunition hoists, is 7.09 inches in thickness, and the turrets for the 9.4-inch guns are protected by armor 7.87 inches thick.

Casemates for the 4.7-inch guns 2.04 inches thick. Circular shields for same, masking ports, 2.83 inches thick. Ammunition passages for these guns have armor 1.97 inches thick.

Conning tower, 3.94 inches of armor; roof, 0.98 inch thick.

Total weight of armor, 1,053 tons.

The armor belt is formed of a single strake of plates which have a trapezoidal section. The lower edge is raised aft to allow for the screws. The armor is of steel, not Harveyized. On each broadside there are 18 plates. Their dimensions are as follows:

	Length in feet.	Thickness in inches.	
		At top.	At bottom.
First plate, at the stem	21.16	7.09	3.94
Second plate	15.51	9.06	4.53
Third plate	15.51	11.02	5.12
Fourth plate	15.19	12.60	5.51
Fifth to thirteenth plates	133.20	13.78	5.91
Fourteenth plate	14.89	12.60	5.51
Fifteenth plate	14.92	11.02	5.12
Sixteenth plate	14.99	9.45	4.72
Seventeenth plate	15.42	7.87	4.33
Eighteenth plate, at stern	20.67	5.91	3.94

The lower layer of the steel protective deck has a thickness of 0.59 inch throughout the ship; the upper layer, over engines and boilers, is 0.787 inch thick; forward and abaft this portion for a distance of 45.93 feet it is 0.59 inch thick, and over the rest of the ship it is 0.39 inch thick, so that the total thickness of the deck in these portions is 1.378, 1.181, and 0.984 inches.

The double bottom extends throughout the greater part of the length of the ship; under the engines and boilers and the forward transverse coal bunker it reaches up at the sides to the bed of the belt armor; under the forward and after ammunition magazines and the after coal bunker, however, it extends only to the foot of the outer lateral longitudinal bulkheads. The thickness of the steel lining above it at this part is only 0.196 inch, while in the central part the middle strake above the keelson is 0.394 inch thick. The double bottom serves for carrying water ballast.

The main deck is constructed of teak 1.97 inches thick, slightly less under the superstructure deck, plated with steel 0.47 inch thick in the central part of the ship, diminishing to 0.2 inch at the extremities.

The superstructure deck has the same thickness of teak, reduced to 1.38 inches above the 4.7-inch casemates, plated with 0.32-inch steel, diminishing to 0.16 inch.

Above the protective deck the protection of the ship is completed by a cofferdam which runs longitudinally through a considerable portion of the ship. The interior face is placed about 3.28 feet from the exterior lining of the ship, and its top at the sides is about 3.35 feet above the upper edge of the belt armor.

The ammunition hoists for the 9.4-inch turret guns and the platform which revolves with them are protected by a steel cylinder clothed with armor; this cylinder having an interior diameter of about 11.5 feet, and extending from the protective deck to a height of about 1.3 feet above the level of the main deck.

In the interior of the protective cylinder is a fixed horizontal platform supported by another cylinder which reaches down to the double bottom.

The barbette armor reaches down to the protective deck and is simply a covering for this outer cylinder.

The armor of the 4.7-inch casemates exists only on the outside. The ports of these casemates are 3.12 feet high. The ammunition hoists are protected by an exterior armored envelope, distant from 3.15 to 3.94 inches all round, having a thickness of 7.09 inches and extending from the protective deck to the floor of the casemates.

DIVISION OF HULL.

The hull is divided by 12 transverse water-tight bulkheads, 10 of which extend up to the protective deck and 2 to the orlop. In the engine and boiler compartments there are on each side 2 wing bulkheads, the inner reaching down to the double bottom and the outer stopping at the height of the floor of the wing passage behind the armor belt.

The bulkheads 'tweendecks and those of the superstructure deck are of corrugated steel and covered with zinc. They have a thickness of about 0.6 inch. At the position of cabin doors this corrugated steel is replaced by steel strips with a teak body.

The walls above the cofferdam and those of the superstructure deck between the 4.7-inch casemates have an inside covering of zinc one-half millimeter thick and this in turn covered with linoleum 2 millimeters thick. In the interior of the cabins the corrugated steel forming their walls is also covered with 2 millimeters of linoleum.

The hammock nettings on the superstructure deck extend between the 4.7-inch casemates, and are formed of two casings, the outer forming bulwarks, and the total thickness of steel being 0.35 inch.

The protective deck, which has no wood flat, is covered with linoleum 7 millimeters thick in the stations, mess places, passages, etc., and 4 millimeters in the cabins.

The powder and shell rooms are wainscoted with 10 millimeters of teak. The bridges are covered with 40 millimeters of teak.

Behind the side armor the teak backing extends over the whole length of the ship, having at its upper edge a thickness of 4.72 inches and 3.94 inches at the lower part.

The conning tower is of rectangular form, with rounded corners. It is placed upon the forward bridge. It is 7.22 feet long, 5.91 feet wide, and 5.25 feet high, and has a thin steel roof.

MOTIVE POWER.

Engines: two vertical triple-expansion engines, each with three cylinders, develop 1,800 horsepower at 135 revolutions and with 24-inch stroke. Weight complete, without water, 193 tons. Weight of water in engines and tanks, 6 tons. Diameter of cylinders, 25.98, 38.58, and 55.12 inches; stroke, 24.4 inches. Maximum revolutions, 135.

Boilers: eight Lagrafel d'Allest type; grate surface, 306.8 square feet; heating surface, 8,800 square feet; ratio, 28.7. Steam pressure in boilers, 213.345 pounds per square inch. Weight of boilers, with funnels, all accessories, etc., without water, 115.9 tons; weight of water in boilers, 20.4 tons; weight of motive power, complete, with water, 335.3 tons. Two furnaces to each boiler.

Coal stored all around the boilers and at the sides of the engines. In the "tranche-cellulaire," on the protective deck, 70 tons additional is carried. Coal capacity at load water line, 190 tons; total capacity, 260 tons.

Endurance at 10 knots, with 190 tons of coal on board, 3,000 miles.

Twin screws.

Auxiliary machinery.—The auxiliary steam apparatus comprises 1 servo-motor for steering gear, 1 steam windlass, 4 dynamos, 2 steam pumps of 300 tons, 1 steam pump of 30 tons, 1 compression pump for torpedoes, 2 ash hoists, 1 deck winch, 2 distilling machines, each with capacity of 1,500 to 1,800 liters in twenty-four hours, 1 auxiliary condenser, capable of condensing 1,500 liters of steam an hour, which receives the escape steam of the auxiliary apparatus ordinarily used for anchoring.

Accommodations.—The cabins of the commander and the second in command are situated in the after part of the superstructure on the main deck. The officers are berthed in the after part of the 'tween-decks under the main deck. The crew have quarters in the central part of both decks. A well-appointed library and hospital are provided.

LOCATION OF ROOMS.

In the after part of the platform deck are located, in the first compartment aft, the steering room; in the second compartment, at the center, the steering motor and gear; at the sides of the same, four storerooms; in the third, center, the training machinery for the after turret, and at the sides, petty officers' rooms and hatches. In the fourth compartment, the electric apparatus, the after pumps, electric and hand winches for hoisting ammunition, rope and sail rooms, and engine storerooms.

In the forward part of the same deck, forward of the boilers, coal bunkers, pump for forward compartments, pump for double-bottom torpedo air-compression apparatus, ammunition winches, water tank holding 4,000 liters, ammunition magazines, provision rooms, after-turret machinery, the steward's room, and other storerooms.

The various bulkheads on this deck, other than the water-tight bulkheads of the ship, are of zincked corrugated steel, without wood or linoleum. The boxes and racks in the storerooms are of wood.

In the hold, the after compartment is empty, and others contain the 9.4-inch ammunition rooms and the ammunition rooms for the smaller guns, and on either side tunnels for the engine shafting, water tanks, and empty water-tight compartments.

The forward compartments contain coal bunkers, ammunition rooms, torpedo rooms, and chain lockers.

The lookout station is placed on the bridge, abaft the commander's station, and constructed of steel.

Masts, rigging, and sails.—The diameter of the two steel pole masts at their passage through the main deck is 0.5 meter and at their tops 0.1 meter. Their total height above the main deck is about 22 meters (72.18 feet). The thickness of the steel runs from 6 to 4 millimeters. The standing rigging is of steel rope. The total sail area is about 1,076 square feet.

Steering gear.—The steam steering gear is placed aft, below the protective deck. It is worked from the commander's station; also by hand, by wheels on the main deck, and at the motor.

Anchors.—The anchor gear includes a steam windlass, 2 cast-iron hawse holes, 2 iron cranes, 2 iron railroads for chain cables, etc.

Two Martin anchors, each of 48.5 cwt.; 1 Martin anchor in reserve, of 48.5 cwt.; 1 kedge anchor of 26.4 cwt., including stock; 1 of 15.4 cwt., stock included; 480 meters (1,574 feet) of chain, 1.73 inches in diameter, for davit anchors; 180 meters (590.6 feet) of chain cable 1.18 inches in diameter; 1 hemp cable 9.8 inches in circumference and 492.1 feet long; 2 hawsers 7.87 inches in circumference and 492.1 feet long; 1 hawser 6.3 inches in circumference and 492.1 feet long; 1 hawser 4.7 inches in circumference and 492.1 feet long; 1 boat rope 3.9 inches in circumference and 492.1 feet long.

Boats.—Steam cutter, steel, 27.88 feet long; wooden launch 29.52 feet long; pinnace 26.24 feet long; two cutters 24.6 feet long; whaleboat for commander 26.24 feet long; dinghy 16.4 feet long; small punt 11.48 feet long.

APPROXIMATE WEIGHTS COMPOSING THE DISPLACEMENT.

		Tons.[1]
Hull: Metallic, wood backing, fitted with accessories of hull		1,027
Armor (including bolts) as follows:		
Sides (and bolts)	505	
Deck with coamings	220	
4.7-inch casemates	76.5	
Circular shields of same	12.8	
Ammunition hoists for 9.4-inch guns	106	
Movable turrets of 9.4-inch guns	124	
Ammunition hoists for 4.7-inch guns	12	
Conning tower	10	
		1,066.3
Armament and ammunition:		
9.4-inch—		
Two 9.4-inch 40-caliber guns, with carriages and supports	68	
Two revolving platforms for same and their machinery	82	
Ammunition, 80 rounds each	47.84	
Equipment, spare parts, etc	2	
Four 4.7-inch 50-caliber guns, with carriages, furnished with 150 rounds	49.96	
Cages for hoisting ammunition	6	
Two 5.9-inch mortars, with carriages and 60 rounds of ammunition	11	
Four 57-millimeter 70-caliber guns, with carriages, stands, and shields, and 400 rounds of ammunition	19.08	
Two 75-millimeter guns, with landing carriages and 300 rounds of ammunition	5.02	
Two 37-millimeter guns, with carriages and shields and 500 rounds	2.616	
Two machine guns (25-millimeter), with carriages and shields and 500 rounds	2.374	
Dynamos, switch boards, etc	16	
Winches and cages for ammunition of 57, 37, and 25 millimeter guns	4	
Small arms and ammunition for same	2.5	
Powder rooms, also miscellaneous	4.61	
		323
Torpedo matériel (submerged tubes)		30.2
Equipment, gear		57
Boats		13
Masts, rigging, and sails		15
Auxiliary machinery		30
Motive apparatus and distilling plant[2]		335.3
Coal (for 3,000 miles at 10 knots)		190
Crew and baggage (200 men, officers included)		23
Provisions and water (provisions for seven weeks and water for fifteen days)		37
Miscellaneous articles and furnishings		15.7
Total, which equals the displacement		3,162.5

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[1] The French ton, or "tonne," the unit of weight in the above table, less 35.4 pounds or 0.02 of a ton, amounting to 1.58 tons in 100 tons, is equal to the English ton. The above displacement of 3,162.5 French tons, therefore, amounts to 3,112.5 English tons.

[2] Weight of engines, 193 tons; of boilers, 115.9 tons; of water, 26.4 tons; total, 335.3 tons.

MARINE CASUALTIES.

ENGLAND.

After her thirty hours' trial the battleship *Glory* returned to Portsmouth on February 8, with the slide rod of her starboard engine broken.

In leaving Sheerness Harbor to join the squadron early in the same month, the *Repulse* ran foul of a barge, which was anchored in the fairway. The starboard quarter of the battleship carried away the topmast of the vessel. The mishap was caused by a strong tide driving the stern of the *Repulse* against the barge.

A small explosion of cordite in the magazine of the *Revenge*, battleship, recently occurred. The cause of the explosion has not yet been ascertained.

The old *Hero*, battleship, is said to have been aground about the 1st of March, but got off again without any damage.

On March 20, while engaged in target practice, a 7-pounder muzzle-loading gun exploded on the battleship *Conqueror*, seriously wounding three men. The accident occurred while ramming home the cartridge.

Defects in the machinery of the cruiser *Arrogant* necessitated her being detached from the channel squadron in November to undergo repairs at Devonport. The feed pumps were found to be leaking and extensive repairs became necessary.

The cruiser *Furious* arrived at Las Palmas December 8, with her machinery in a defective condition, the cause of complaint being similar to that which necessitated the *Arrogant*, a sister ship, being sent back to Devonport. The *Furious* was laid up at Las Palmas for some weeks, and her engine-room staff did their best to repair the leaky joints and otherwise render the vessel efficient.

Monday, March 5, the cruiser *Hermes* arrived at Nassau, Bahama Islands, with her shaft broken and boilers damaged. The cruisers *Crescent* and *Proserpine* hurried from the Bermudas to assist the *Hermes*.

From Durban it was reported on February 6 that a somewhat serious accident had occurred on board the cruiser *Thetis*, a boiler having exploded, causing the deaths of two men.

At Buenos Ayres the British steamer *Trefusis* and the cruiser *Pegasus* were in collision in February. The former had several plates bent or broken and the forehold full of water, but the cruiser appears to have got off without serious damage.

During target practice on board the gunboat *Melita* in the Black Sea the explosion of a gun resulted in the death of one man. The *Melita* carried eight 12.7-centimeter and eight machine guns.

A Reuter's telegram from Hongkong, April 7, stated that the river gunboat *Sandpiper* was ashore near Samshui, on the West River. She was badly damaged. The torpedo-boat destroyer *Fame* was going to her assistance. The *Sandpiper* was refloated and reached Hongkong safely and went into dock, having sustained damage to her bottom.

While running one of her series of 1,000-mile trials the torpedo gunboat *Seagull*, December 12, fouled the chain of the East Sturbridge buoy at Spithead, and the chain having become twisted round the vessel's propeller the trial had to be suspended.

Tuesday, February 7, the destroyer *Teazer*, attached to the gunnery establishment, Whale Island, went out to Spithead to adjust compasses, and on returning collided with the North Corner Jetty and very seriously damaged her bows.

The first cruise of the reorganized Devonport instructional flotilla of torpedo-boat destroyers was attended with a very unfortunate mishap. February 12 the *Panther*, *Wolf*, *Seal*, *Thrasher*, *Bat*, *Locust*, and *Osprey* left Plymouth for a cruise in the Channel, but were driven by boisterous weather to seek shelter in Falmouth Harbor on the 14th, where they were joined late in the afternoon by the *Fairy*, which had been detained at Devonport in consequence of machinery defects. Shortly after midnight the heavy wind and seas caused the *Fairy* to drag her moorings, and she was swept down first on the *Locust* and then on the *Osprey*, damaging both vessels and smashing her own boats and fittings. Unable to get a grip for her anchors, the *Fairy* dragged toward the *Bat*, and to prevent another collision the *Bat*, with the *Seal*, *Wolf*, *Panther*, and *Thrasher*, weighed their anchors with a view to steaming to a safer anchorage. Before this could be effected the *Fairy* was run into by the *Bat*, struck just amidships on the port side, and in the darkness it seemed as if she would be cut in two. Skillful manœuvring of the *Bat*, however, prevented this disaster, and by 5 a. m. all eight vessels were securely moored. A sub-lieutenant on the *Seal*, unfortunately, severely twisted his ankle by being caught by the cable when his anchor was being weighed.

The damage sustained by the destroyers was of a serious character. The *Fairy* lost a Berthon boat and a whaler, both of which were smashed to pieces; her stern frame and plates were badly crippled, letting water into the steerage compartment; she was badly knocked about on the port bow and at the port gangway, and it was feared her propellers were broken. The *Locust's* damage was confined to the fore part of the vessel; the stem was badly twisted and several plates and frames crippled. The *Bat* was damaged on the starboard quarter, her starboard propeller guard smashed off, her bow damaged, and the fore compartment and wardroom leaking. The *Osprey's* damage was confined to the loss of a few fittings, which were carried away when the *Fairy* grazed her side.

Following on this adventure a rather more serious accident happened to the *Bat* February 21. Though unattended by loss of life, the accident resembles in nearly every other respect the late mishap to the *Bullfinch*, when eleven lives were lost. During an hour's run at full speed in February everything was apparently going well, engines running about 360 revolutions, and 28 knots logged. The hour was nearly up, when a loud noise was heard, followed by a rush of steam. Steam was promptly shut off, and the men, eight in number, succeeded in escaping from the engine room without injury. After the débris had been cleared away the full extent of the damage could be clearly seen. The prime cause can be traced to the cap of the low-pressure crosshead brasses, which fractured across one of the bolt holes; but whether this was due to inherent weakness of the cap or to a crosshead bolt nut slacking back and bringing extra strain on the cap remains for a court of inquiry to decide. As a result of this fracture the connecting rod was free, and blows from this part bent the crosshead guide back to an angle of 20 degrees and made a huge bulge in the port condenser. The piston, being also free, knocked a hole in the cylinder cover. On the cylinder lagging being removed a huge fracture was found in the cylinder itself, extending for several feet, the crack being at least two inches wide.

The destroyer *Angler*, of the Medway instructional flotilla, returned to Chatham early in March with her stem cut through and the plating of her bows badly bulged, the damage having been caused by a collision.

Torpedo boat No. 36, employed in patrolling the West River in China, was wrecked in February a short distance below Kumsank. It is said that she was very badly damaged, having struck a rock and ripped out a good portion of her bottom.

Torpedo boat No. 92, while steaming at a high rate of speed, ran stem on to the light-ship moored just outside the entrance to the mole at Gibraltar, in November. The force of contact was so great that the bow was deeply buried in the side of the light-ship. The bow was withdrawn, and the light-ship gradually settled and sank. The cap of the bow tube of the torpedo boat was smashed, and on examination her fore compartment was found to be leaking.

Victoria and Albert, the new royal yacht, which was to have been undocked at Pembroke January 10, met with a serious accident. When sufficient water had been admitted to float her, she heeled over to port about 25 degrees in the dock. The caisson was replaced at the dock entrance and every effort made to keep her afloat until measures could be adopted to right her. From some cause, however, the caisson jammed before it was completely closed, and the decrease in depth of water in the dock resulted in her port bilge resting on the keel blocks along the middle of the dock. Her stem was pressing against the granite at the upper end, and her stern crushing into the caisson. The yacht, after having been partially righted with pig-iron ballast, was undocked the next morning with a list of 10 degrees.

In the calculations many of the weights, especially those connected with the structures composing the upper portion, appear to have been greatly underestimated, and various additions to these weights, among them an increase in the mast heights, were sanctioned during her construction. The result was that she was actually unstable when upright. A considerable amount of crushing in of the outer bottom occurred, but the inner bottom was only injured to a slight extent. The masts and funnels have been shortened, and the greater part of the forecastle cut away.

The new destroyer *Recruit* met with a serious mishap during her steam trials at Portsmouth. She left the harbor during the forenoon of May 8, the engines being in charge of the contractors, Messrs. John Brown & Co., of Clyde Bank, and proceeded to Stokes Bay for three hours' full-power trial. After having run a little over two hours the studs on the low-pressure eccentric strap carried away and the balance piston knocked out the end of the balance-piston cylinder. Fortunately no one was injured, and the *Recruit* steamed back to harbor.

FRANCE.

April 14, while four engineer officers on board the *Massena*, battleship, were dismounting an escape pipe in order to clean it, by accident they disjointed the parts too rapidly. Steam concentrated in the escape pipes and, escaping in all directions by numerous joints, burned the men badly.

On board the armored cruiser *Chanzy*, in February, while the squadron was getting under way at Toulon, an explosion of steam in one of the boiler rooms burned several men, one of whom died.

February 22, after engaging in target practice with the squadron, the torpedo-boat destroyer *Hallebarde* was assisting in picking up the targets of the *Gaulois*, and came into collision with that battleship. The bow of the battleship struck the destroyer on the starboard side just behind the last but one water-tight compartment. The plating was torn off over a length of 5 meters, and water rushed into the compartment; but the water-tight bulkheads prevented its gaining other parts of the ship, and the *Hallebarde* was able to return to Toulon at 10 knots speed, escorted, for the sake of prudence, by the *Dunois*.

During this same practice the *Cyclone*, while towing a target, was torpedoed by the *Flibustier*. The latter launched two torpedoes with practice heads, both of which deviated a great deal from their proper course. The first passed across the bow of the *Cyclone*, but the second one struck the side of the *Cyclone* about 40 centimeters from the stern, but disengaging itself, did little damage.

In February the seagoing torpedo boat *Sarrazin* sustained a slight accident to her rudder and was docked for repairs.

About the same time the destroyer *Dunois* ruptured the frame of one of her service engines, and a period of twenty to thirty days was necessary for the repairs.

The seagoing torpedo boat *Grenadier* was slightly injured by collision with a pilot boat in leaving the harbor of Havre, and subsequently, on account of the attempt to evade this collision, she injured her bow by colliding with a jetty.

While engaged in torpedo exercise at night, the torpedo boat *Doudart de Lagree*, forming part of the mobile defense of Algiers, collided with another torpedo boat and sustained considerable damage to its bow.

An accident occurred on board torpedo boat No. 228, near Cherbourg, March 31. She was steaming at a speed of 25.5 knots, when the piston rod broke. Five men were severely scalded by escaping steam, one of them in his agony sprang overboard and was drowned, and two of the others were not likely to live at last accounts.

GERMANY.

Battleship *Kaiser Friedrich III* ran aground while entering the dry dock of the Government shipyards at Kiel, sustaining injuries to the bow torpedo-launching tube.

On February 27, at 3.45 p. m., in foggy weather, the battleship *Sachsen* ran aground near buoy "Kiel A," and on March 1, at 2.30 a. m., at rising tide, she got off under her own steam. The injuries sustained were of little importance. The outer skin of the bottom on the port side was dished in several places and torn open. The time required for making repairs was about two weeks.

Between Danzig and Kiel, during the night of April 7, the battleship *Weissenburg* collided with some unknown object while making a run with forced draft. The double bottom was injured and filled with water, and the ship was docked at Kiel.

During target practice on the morning of November 25, 1899, the battleship *Worth* struck a rock in the Bay of Eckernförder and tore a hole 22 feet long in her bottom, flooding three compartments. She went into Wilhelmshaven for repairs, and exactly one week later, contrary to expectation, she was in condition to join the squadron in its cruise to Norway. Although no vital portions of the ship were directly involved in the injuries sustained, it was necessary to close the large rents in the outer skin on the starboard side by riveting on temporary plates, while on the port side the joints in the plates had to be riveted anew. This work was pushed night and day by a great number of workmen. Before being docked, moreover, the *Worth* had to unload her entire coal supply of 500 tons, and this had to be returned to the ship after the repairs had been made.

Fire broke out on board the station ship *Loreley* in November, and two sailors were severely burned.

Torpedo division-boat D-3 broke her screw shaft during a practice cruise and had to go to the navy-yard at Kiel for repairs.

During target practice in Flensburg Bay torpedo boat S-81 sustained some injuries to her bow below the water line.

March 13 a torpedo boat collided with a sailing ship near Kiel, and was helped out of her difficulty by the cruiser *Jagd*.

RUSSIA.

The battleship *Poltava* ran ashore January 16 near Libau and lay in a dangerous position, but is said to have got off and been towed to Libau without serious injuries.

In a gale during a snowstorm on a very dangerous coast the coast-defense ironclad *General-Admiral Apraxin* went ashore off Hogland on November 12 last and was lifted and flung onto the rocks, which here formed a species of **W**, the central apex of which penetrated her bottom. A rent was made 6 feet long by 4 feet wide on the starboard side of the stem. The wound was deep, as the rock penetrated the hull and projected into one of the ammunition rooms. There were also comparatively small indentations on the port side. The ship was embedded firmly between two rocks in such a manner that two-thirds of her length was free and one-third embedded in comparatively soft stone. The vessel had no other injuries, and as precautions were taken in sending out anchors ahead and astern, could not move. The portion of the rock which penetrated the vessel was cut off, the hole patched by divers, and the vessels which went to her assistance succeeded in pumping out the water so that the auxiliary boiler could be used. It is said that later, in January, the *Apraxin* was driven by a mass of ice on a rock which pierced a fresh hole in her hull. It finally became necessary to lift the ship, as well as blow away the rocks around her, and this in very bad weather. Great credit is due to the Russians for their persistence in carrying out the work, which seems to have been an engineering feat of no small order. A last desperate effort got her off May 2, though she was very badly damaged, and in the end the famous ice breaker *Ermack* assisted in floating her.

The *Gromoboi*, cruiser, grounded on a sand bank while on her way from St. Petersburg to Cronstadt. She was in a difficult position, but favorable weather permitted her being safely floated.

The cruiser *Admiral Nakimoff* got nipped in the ice during the winter and had to go to Cherbourg to refit. She was coming out of Cronstadt when the casualty occurred, and, the sea being frozen, the *Ermack* made a way for her. At the edge of the ice field, floes were encountered, and in picking a way among these, the cruiser got into a cul de sac. The damage done was not, however, very extensive, since she was at Spezia not long ago.

SUBSEQUENT CAREER OF THE ICE BREAKER ERMACK—MISHAPS.

(*See* page 141 and pages 156-160 of General Information Series, No. XVIII.)

On July 25, 1899, the *Ermack* struck the ice boundary north of the northwest corner of Spitzbergen, in 80° 20′ latitude and 9° 21′ E. longitude. She steamed north and proceeded successfully. Under slow steam, ice fields of 4.08 to 4.77 meters thickness were broken without difficulty. The accumulations of ice she met were at times 14.9 meters thick and rose 6.13 meters above the surface of the sea. After several of them had been successfully broken, the *Ermack*, on July 26, struck with the comparatively weak underpart of her hull on the spur-like projection of a block of ice of that nature and sprung a leak. This was temporarily repaired and the voyage continued, but in spite of every possible care the damaged portion of the ship came once more into violent contact with the low-lying blocks of ice, the leak was enlarged, and finally the voyage had to be abandoned. On August 17 the *Ermack* started for Newcastle in order to return to the dock which she had but recently left. As yet it does not appear to have been decided whether her bow is to be thoroughly strengthened in order to enable her to take up the battle with polar ice, or whether it is merely to be restored to its former condition for the purpose of operating in the Gulf of Finland, where the ice, though harder, is less powerful than in the Arctic Ocean.

The failure of the *Ermack* upon her second attempt to penetrate the polar ice is considered by many as a final condemnation of Makarof's idea—unjustly so, however, for the following reasons:

The main principle which lies at the foundation of Makarof's idea is that the ice of the oceanic ice fields is in summer of such slight resistance that it can not withstand the shock of a ship of 8,000 tons displacement and 10,000 H. P. The experiments have shown that the *Ermack* with 7,500 H. P.—that is, with her forward engine of 2,500 H. P. uncoupled—is able, while running with moderate steam, to break through the polar ice north of Spitzbergen, which is many years old and considerably compressed. If in doing so she sustained some injury to the comparatively weak bow below the thick ice belt, it simply demonstrates that the forward part of the ship must be considerably strengthened in its whole extent, probably in the same manner as is now the case at the water line.

In the execution of this novel and bold idea, in which not only technical difficulties had to be overcome, but also justified and unjustified doubts and prejudices, it is very evident that some defects were unavoidable. It is obvious, for instance, that the forward screw of the *Ermack* can be of no use whatever in polar seas, and therefore the whole forward engine and boiler can be done away with. The saving in weight resulting therefrom can be utilized to strengthen the bow and give it the same resistance in the lower part which it now has at the ice belt.

The building yard is bound by contract to furnish the *Ermack* with sufficient resistance to enable her to withstand the impact with ice. Any repairs which may be required have to be made by the constructors without extra charge.

JAPAN.

April 30 the Japanese battleship *Asahi* grounded on Southsea Beach. The battleship was coming out of Portsmouth, England, under her own steam, with an experienced pilot on board and was well in the center of the fairway, but the channel is very serpentine and narrow, and at several places along its edges it suddenly shallows. Suddenly, abreast of a shelving bank, she was carried inshore, her ram dug into the bank, and she lay broadside on with her stern toward Clearance pier. This was at flood tide. As the tide went down it fortunately carried her stern around, and she lay with her bow shorewards. She listed to port, and at the ebb about 20 feet of the bow was exposed, a good deal of bottom below the five submerged tubes being visible. The stern was still awash. The danger of straining the hull was imminent, but a little after midnight the ship floated, with very little injury having been done. Some of the frames were bent internally, but whatever harm was done was comparatively slight. Much mystery obscures the true cause of the accident. The best and most probable explanation offered is that the ship was not steaming fast enough to be under proper control in the state of the tide at the time.

A collision occurred December 28, at about 9 p. m., between the cruiser *Chitose* and a fishing schooner near the island of Oshima, the schooner being sunk almost immediately.

TURKEY.

The torpedo boat *Seham*, built at the Germania Works in 1892, of 85 tons displacement, 1,300 I. H. P. and 22 knots, was lost on April 21 in the harbor of Beyrout, in consequence of a boiler explosion. The crew, comprising 27 men and 2 officers, lost their lives.

GREECE.

Torpedo boat No. 12, by an explosion of the boilers, was lost at the arsenal at Piræus while taking coal, and 8 persons killed.

III.

NOTES ON GUNNERY, ORDNANCE, AND ARMOR.

By Lieutenant-Commander RICHARD T. MULLIGAN, United States Navy,
Staff Intelligence Officer.

TARGET PRACTICE.

The value of properly conducted target practice can not be overestimated, and that it is a subject of continually increasing importance is shown by the fact that all naval powers are devoting more time and money—that is, ammunition—to the careful and systematic training of gun pointers. Extra monetary inducements are offered to encourage men to become expert marksmen. For instance, the British Admiralty has decided to distribute annually £5,200 in prizes for the encouragement of shooting with the various weapons used in the royal navy. This action makes it clear, at least in so far as England is concerned, that the subject is regarded as one of supreme importance.

The main object of target practice is to train men to hit a target under conditions approaching as nearly as practicable those of real battle. They must be taught to point their weapons quickly and accurately and fire without unnecessary delay. This last is most important, for fire to be efficient must be not only accurate but rapid. A skillful gun captain should also be able to properly estimate the distance by the eye.

A great deal of time has in past years been devoted to methods of plotting gun practice, ratios of merit to be given to shots *off* the target, etc., and the main object, that of actual hits, has been of secondary importance. It is not of infrequent occurrence to hear the gunner instructed to "shoot high," as his "final score," according to the usually followed system of obtaining percentages, would probably be thereby increased. This has, in a measure, grown from the fact that the target used is too small to be hit except by a chance shot, and it is, in consequence, difficult for the gunner to keep it in sight.

The enemy's vessel, except when obscured by smoke, will always be visible, so that to make the conditions of practice assimilate as closely as possible to those of actual combat the target should be large enough to be plainly seen and actual hits noted. A few yards of canvas bobbing about spasmodically, as the target appears when looked at over a gun's sights, present a most unsatisfactory appearance. This motion of the target, which is rarely absent on the open sea, tends to rattle the marksman and take his mind from the other and more important elements which enter into his problem. To partially eliminate this source of error it now seems generally recognized abroad that the target, especially for prize firing, must be a large one. That recently used by the English is of the shape and approximately of the dimensions shown in figure 1. It is merely a raft with three masts having canvas stretched between them. The triangular jibs at each end are used only for heavy barbette and turret guns, the modern rapid-fire guns having proved that it is too easy a mark for them when at its full size. The target is towed out to its position and moored head and stern, so that it will always lie in the same direction, and three buoys are then laid out as shown in figure 2. Only actual hits are scored. Speed, 12 knots. A "time allowance" is fixed for each class of gun.

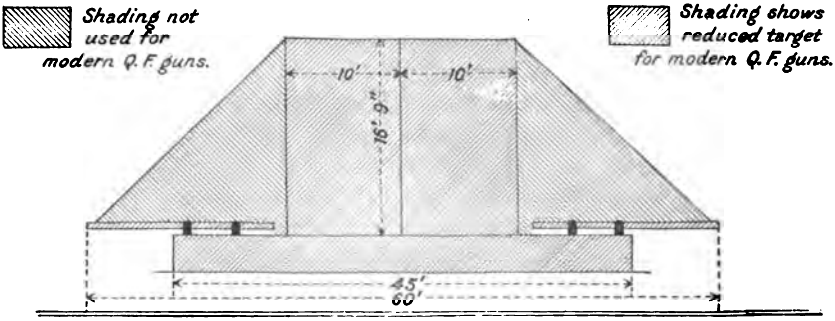

Shading not used for modern Q. F. guns.
Shading shows reduced target for modern Q. F. guns.
10'
10'
16' 9"
45'
60'

FIG. 1.—British prize firing target.

The Admiralty has recently issued an order that when a ship goes out for prize firing at least two officers from other vessels shall attend as umpires. That they are determined that their gun pointers shall be kept at all times at a high state of efficiency is shown by a recent order, which requires all captains of guns on home stations who are not engaged in such service as necessitates their firing the required number of rounds from the guns in a seagoing ship, to be sent to the nearest gunnery school at least twice a quarter, and there they are to fire their quota of both large and small projectiles.

The amount of ammunition that is to be expended during each year has recently been increased, but reliable information as to the number of rounds for each class of gun does not appear to be forthcoming. More time is given to subcaliber practice than formerly.

The commander in chief of the Mediterranean station has recently ordered that target practice with small arms shall be conducted at floating targets. This is deemed to be most effective exercise on account of the striking of the bullet on the water being visible to the man who fires it, which is not the case at ranges. At least twenty rounds are to be fired from each rifle on board during each quarter, except that in which the annual rifle practice takes place. It is further directed that if it is not possible to fire all of the quarter's allowance under these regulations, the amount to be expended is to be fired the next quarter in addition to the ordinary quarter's allowance.

The data in regard to target practice that have from time to time appeared in the press are usually defective in that in almost each instance some important factor (if the figures are to be used for purposes of comparison) is missing. It is quite usual to find that one of the elements, either the speed, size of the target, or ranges, is not stated.

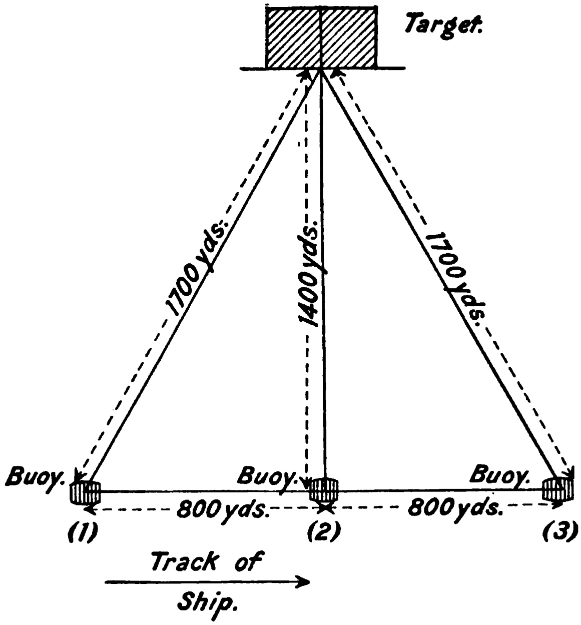


FIG. 2.

The regulations for towing-target practice as conducted by the British Mediterranean squadron, require that the vessels shall form in two columns, 1,200 yards apart, and move in opposite directions. The distance between ships is 1 mile. Each vessel tows a float (size not given) 500 yards astern, which is fired at in succession by the vessels of the opposite column. Observers on each ship note the fall of the shots near the target astern and signal the results to the vessel firing. The speed of the whole force is set at 8 knots. The projectiles are filled with salt.

It is probable that it was under the above-mentioned conditions that the following practice with 6-inch, 4.7-inch, and 12-pounder quick-firing guns took place in November last:

Ship.	Number of men firing.	Number rounds fired.	Points.	Points per round.	Per cent score.
Cæsar	Not stated.	29	342	11.8	98
Ramillies	14	28	288	10.3	86
Venus	10	20	203	10.1	84
Hood	7	24	232	9.7	80
Empress of India	20	40	370	9.25	77
Revenge	7	28	258	9.21	76
Dido	9	20	184	9.20	76
Royal Sovereign	8	25	227	9.08	75.6
Renown	12	48	423	8.8	73

Shots lost to view: *Hood*, 2; *Dido*, 1; *Renown*, 4; *Empress of India*, 7; *Royal Sovereign*, 1; *Revenge*, 3 *Ramillies*, 1.

During the same month the British Channel squadron is reported to have held towing target practice, ships working in pairs, 2 miles apart; speed, 6 knots; ranges, 1,500 to 1,000 yards; target 20 feet long by 16 feet high.

It may be that targets of the same size were used by both squadrons.

The following table gives the results of towing target practice carried out by some of the ships of the Mediterranean squadron when cruising in company on January 24. The practice was limited to 6-inch guns. The target was towed at about 8 knots per hour, and the distance of the target from the ship firing varied from 1,000 to 1,500 yards. The weather was calm, with the surface of the water slightly broken.

Ship.	Number of men firing.	Rounds fired.	Points made.	Lost shot.	Average points per round.
Andromeda	32	64	687	1	10.7
Theseus	20	40	420	0	10.5
Royal Oak	20	40	405	3	10.1
Royal Sovereign	20	40	390	1	9.7
Canopus	22	48	463	6	9.6
Astræa	6	12	109	2	9.0
Total	120	244	2,474	13	10.0

These results are fairly good. The proportion of lost shot was small. The *Andromeda* made by far the best average, although no less than 32 men fired, which means that the firing was not limited to the captains of guns, but numbers 1 and 2 fired as well. Taking this into consideration, the results obtained by the *Andromeda* certainly point to a very efficient state of gunnery in that ship, and show that the training has not been confined to a small number of seamen gunners who are crack shots.

PRIZE FIRING ON THE MEDITERRANEAN STATION.

The results of last year's prize firing, as they appear in the *Journal of the Royal United Service Institution*, are as follows:

Heavy gun prize firing—i. e., 9.2 to 13.5-inch guns.

Vessel.	Gun.	Per cent of hits.
Illustrious	12-inch	55
Revenge	13.5-inch	53.8
Cæsar	12-inch	52
Ramillies	13.5-inch	50
Empress of India	12-inch	46.4
Do	6-inch Q. F. guns	46.9
Scylla	do	45
Ramillies	do	42
Revenge	do	38
Scylla	4.7-inch Q. F. guns	80
Vulcan	do	51
Thetis	do	42.4
Hazard	do	41
Hebe	do	35
Anson	6-inch Q. F. guns	26.3
Rupert	do	13.3
Camperdown	do	17
Empress of India	Secondary battery (light Q. F. guns)	49.1
Thetis	do	47.5
Salamander	do	43.9
Renown	do	40.6
Hood	do	36.2
Hawke	do	36
Cæsar	do	32.6
Hebe	do	31.2

MACHINE GUNS.

Melita	1-inch Nordenfelt, 2-barrel	35.3
Anson	.45-inch Nordenfelt, 5-barrel	21.7
Cockatrice	1-inch Nordenfelt, 2-barrel	20.7
Ramillies	.45-inch Maxim	20
Vulcan	1-inch Nordenfelt, 2-barrel	19.8
Thetis	.45-inch Nordenfelt, 5-barrel	16.1

The target used for firing with these guns is usually triangular on the base, with vertical sides. The target as it appears is 12 feet by 5 feet. Speed, 8 to 12 knots. Distance, about 1,000 yards. A certain "time allowance" is given each weapon, and only actual hits score.

In connection with the above, it is interesting to note that in mere percentage of hits the palm was carried off by the *Scylla*, viz., 80 per cent. She fired 70 rounds of 4.7-inch shell and hit the target 56 times. The practice was conducted in a light swell. In big gun work the *Illustrious* shows to the best advantage, 55 per cent of her 12-inch shots hitting the target. Three other battleships also made 50 per cent and upward of hits with their 12-inch and 13.5-inch guns.

It is reported that during a recent practice the *Blake's* best gun crew fired 18 rounds and hit the target 15 times, while the total number of rounds fired by the guns was 148 and 110 hits recorded. The *Royal Arthur* did nearly as well; her best gun fired 18 rounds and scored 14 hits. The conditions of this practice allowed each gun crew three minutes in which to score. The range at the beginning was 2,200 yards, diminished to 1,600, and finally increased to 2,200 again.

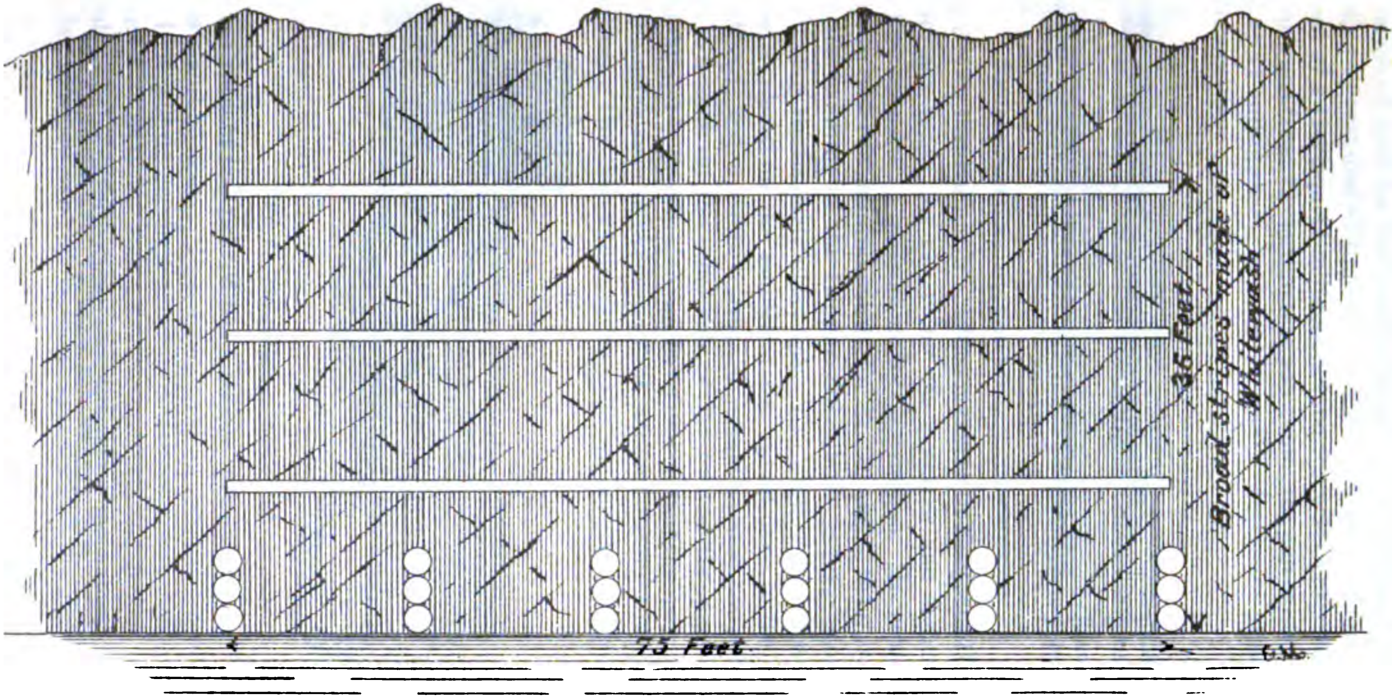
No returns of French target practice have been noted since that held at Mèdes Rocks in August last. The available data concerning this practice is given on page 259, of General Information Series No. XVIII, As neither size nor shape of the targets is given, nor the speed at which the vessels steamed while firing (all factors that must be known in attempting to criticise naval gunnery), no fair comparisons can be made with the practice of the English given in this article. If we assume that the French target, as usually laid off on the Mèdes bluff, was double the size of the English, that the speeds were the same, the difference in the ranges being taken into consideration, the performance of the *Cassard* (72 per cent of hits in 9 minutes) compares very favorably with that of the *Scylla's* 80 per cent record. The practice of both squadrons was excellent.

In naval warfare the ship which can get in the most hits in the shortest time is of the greatest strategical value. In other words, a vessel which can make 80 per cent of hits (in a given time) is the tactical equivalent (in an engagement) of two sister ships making 40 per cent of hits.

The very *raison d'être* for a ship is that she shall be able to fight efficiently. To do this she must be able to capture or destroy her enemy. It seems to be accepted that sea fights of the future will be of short duration, and, if such be an axiom, it is safe to assume that the victory will rest with the ship that gets in her hits first. If these statements are undisputed, all else on board ship should be subordinated to the training of gun pointers.

In the *Navy League Journal* of April, 1900, the following important details are given: The target used by the French Mediterranean squadron at the Rochers des Mèdes measured 36 feet by 75 feet, or a total area of 2,700 square feet (fig. 3). The speed was from 10 to 12 knots and the range varied from 3,300 to 4,600 yards. The area of the English service target was 587 square feet for the heavy guns, and 309 square feet for the medium quick-firers. The speed was 8 knots, and the range varied from 1,400 to 2,000 yards. The conditions of the practice of the two squadrons were, therefore, wholly dissimilar.

The German press is silent upon the subject of their target practice, but that they are keenly alive to its value and necessity is apparent from the fact that in this year's naval budget an appropriation of 2,027,000 marks (about $482,326) has been made for ammunition, target practice and prizes. This is an increase of about $71,000 over the


35 Feet.
Broad stripes made of Whitewash
75 Feet
G.We.

Rochers des Mèdes, Hyères Islands.
Fig. 3.

THE NORRIS PETERS CO. PHOTO-LITHO. WASHINGTON, D. C.

appropriation of 1899 for the same purpose. It is reported that they are devoting a great deal of time to subcaliber practice. Figure 4 is an illustration of a German 47-millimeter tube for a 15-centimeter R. F. gun. For guns from 12 centimeters and above, the sub-caliber tube is from 57 to 47 millimeters, and for 10 and 9 centimeter guns, of 37 millimeters caliber.

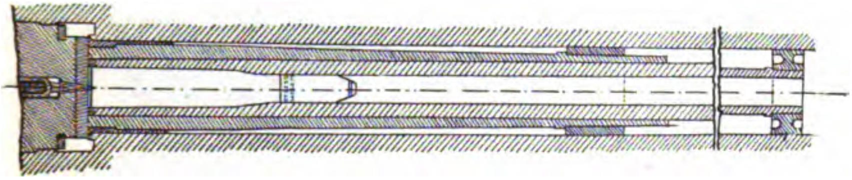


FIG. 4.—German 47 mm. subcaliber tube for 15 cm. rapid fire gun.

Figure 5 is an illustration of a device invented by Sergeant Hummel, of the German army, for observing the pointing and sighting of a rifle in the hands of a person under instruction. It enables the instructor to observe simultaneously the line of sight, the marksman's eye, and the handling of the trigger without the pupil's being aware which is being particularly observed. The semicircular foot of the apparatus is placed on the mantle of the barrel close to the head of the breech box, and a rubber strap is passed around the stock and attached to a hook on the other side of the foot of the device. The mirror sight and indicator case can be so moved that the instructor can observe the marksman in every position without having to change his own position. This saves time during the instruction. It is claimed that the instrument has proved to be simple, practicable and durable. Its cost is about 85 cents. It is being used in several German regiments. If it will do one-half of what is claimed for it, it would seem to be worthy of trial.

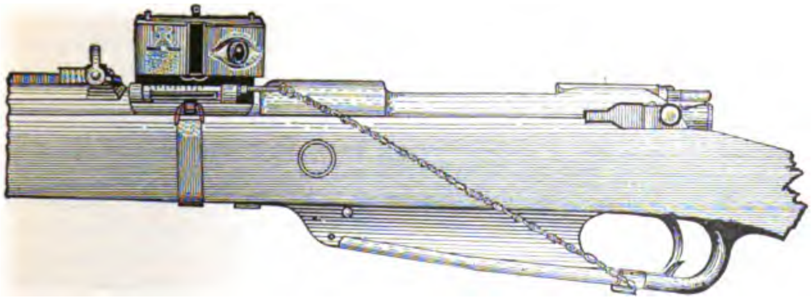


FIG. 5.—German sighting device.

The only reliable information from Russia on the subject of target practice is contained in a report which appeared in the *Kotlin*, as follows:

At the trials which recently took place in the presence of the minister of war, 130 rounds were fired from 4 mortar batteries against a target consisting of 2 sloops connected with each other and towed by a steam cutter at the rate of 10 knots, and at a distance from the batteries varying between 2⅔ and 4 miles. This target was 280 feet long and 28 feet wide. Of the 130 rounds fired only 8 hit the target, which, as the projectiles contained no explosive, sank after the eighth hit. Many projectiles fell so close to the target, however, that if the latter had been a warship, 24 of them—that is to say, 18 per cent of the total number of projectiles fired—would have hit. But in modern naval warfare, ships that are being fired upon will change their speed intentionally in order to increase their chances of not being hit. On the whole, the trials seem to prove that, while it is quite possible for mortar batteries bombarding an attacking fleet to set a ship out of action with bursting shell, this advantage is almost annulled by the large percentage of ineffective projectiles. Hence, unless the number of mortars can be increased to such an extent that it becomes possible to throw a veritable hail of projectiles upon the advancing fleet, it does not appear advisable to rely exclusively upon mortars for the defense of coast fortifications and to neglect the ordinary heavy artillery.

These firing trials were made with the mortar batteries at Kronstadt, for the purpose of ascertaining whether it would be possible to check an advancing fleet with their fire. As the report intimates that the ranges and the speed to be maintained by the target were known to the gunners, the results of the practice can not be regarded as very satisfactory.

The following extracts from a lecture delivered by Capt. J. A. F. Graham, of the Swedish navy, before the Royal Naval Society of Carlskrona, are given in full, as the data contained therein are undoubtedly reliable and his comments upon the results obtained are interesting and instructive:

> While the technical arrangement of a ship's armament requires the greatest care, yet it is the use made of the guns during battle that determines the issue. To hit will ever remain the first object of gun fire, and careful practice and training in firing are the only effective means for attaining this object. * * *
>
> But it can not be denied that the technical arrangement of modern guns exerts in some respects the greatest influence on the perfection in firing. This applies first of all to the arrangement of the sighting devices. For heavy and medium-caliber guns the gun captain himself has to elevate as well as train the gun and fire it by means of wheels and a crank. This is now considerably more difficult than the training and firing which the captains of older guns had to do. "If our gunners had three hands," says an English naval officer who is in the employ of the firm of Armstrong, "the training and firing of modern guns would be an easy matter. But how is a gun captain with two hands to manage two wheels and one crank?" To remedy this difficulty, experiments have been made in dividing the training and firing between two men of the gun crew, either so that one of them does only the training while the other does the elevating and firing, or so that the firing is done by orders of the training gunner. The former of these alternatives requires a coupling together of the sights.
>
> The experiences gained during the year 1899 from target practice, at the gunnery training school, with 12-centimeter R. F. guns M/94, point in the direction above indicated. Especially in a seaway the training of guns is connected with difficulties if the rapidity of fire is to be preserved.
>
> The 15-centimeter guns of the *Dristigheten* have vertical as well as lateral training wheels on both sides of the mount, so that in this case it is not difficult to divide the operations of training and firing as stated.
>
> Great requirements must be made of the sighting devices themselves in order that the effectiveness of rapid fire may be maintained, and the more the range of guns is

increased the more the need is felt of a sight which will permit the target to be more clearly distinguished than is possible with the naked eye. Among the improved sights there are really only two types which have attracted general attention, namely, the so-called H-sight and the telescopic sight. The former may be of different forms. It either consists of two small uprights with a horizontal wire stretched between them, at the center of which is the front sight in the shape of a circular disk, or, like the German naval sight, it is constructed in the shape of a frame between the sides of which are stretched one horizontal and two vertical wires; the front sight is on the horizontal and between the two vertical wires. The advantages of these sights are that the target is visible below as well as above and on either side of the sighting line, and that it is very easy to learn the relative positions of the front and breech sights. * * *

It is a generally recognized fact that the annual target practice promotes in a high degree the skill of our naval gunners. To show this, a few of the results attained at the gunnery training school during the year 1899 may be mentioned.

Prize firing with 12-centimeter R. F. gun M/94, at anchor, against large stationary target; distance, 1,200 meters; moderate rolling and pitching; calm:

Number of rounds.	Total number of points.	Time.		Prize.
		m.	s.	
First-class seaman, 3	10+10+10=30	1	45	First prize and medal.
Seaman gunner, 3	10+10+10=30	1	48	Second prize.
Second-class seaman, 3	10+10+ 6=26	0	51	First prize.
Second-class seaman, 3	10+10+ 6=26	1	23	Second prize.
Second-class seaman, 3	10+10+ 6=26	1	30	Third prize.

Prize firing with 57-millimeter R. F. gun M/92; under way; speed, 12 knots; target, cross section of torpedo boat; distance, 1,000 to 600 meters; force of wind, 3 to 4:

Number of rounds.	Number of hits.	Time.	Prize.
		Seconds.	
First-class rigger, 3	2	12	First.
Second-class rigger, 3	2	14	First.
Second-class rigger, 3	1	16	Second.

In the above results the small rapidity of fire attained with the 12-centimeter R. F. gun M/94 must at once be apparent. This is due to the fact that in the Swedish navy the requirements in that respect for obtaining prizes are not severe, so that there is not much incentive among the pupils of the gunnery school for forcing the rapidity of fire.

There also took place at the gunnery training school competitive firing on board the gunboat *Urd.* The target was a torpedo cruiser of one-third size; the speed was 5 knots; the distance 2,600 to 1,200 meters. The firing was done under way, both going toward and moving away from the target. In the following table, showing the results, the trial shots are included under "Number of rounds:"

Gun.	Number of rounds.	Per cent of hits.	Remarks.
12 cm. R. F. gun M/94	10	50	The inferior result of the 12-cm. gun M/81 may probably be attributed to the condition of the practice ammunition.
12 cm. gun M/81	3	0	
57 mm. R. F. gun M/92	58	33	
36 mm. R. F. gun M/84	6	67	
25 mm. machine guns M/77	72	10	

The results of the competitive firing of the coast squadron in the year 1899 are shown in the following table. Owing to the swell prevailing, and for other reasons, the hits could not be taken down accurately; the results must therefore be considered approximate. The speed was about 8 knots. Target, battleship section 3 x 8 + 3 x 15,[1] and gunboat section. The trial shots are included:

Class of ship.	Guns.		Distance.	Per cent of hits.		
	Number.	Caliber.		Maximum.	Minimum.	Mean.
First-class battleship	6	25 cm. M/94	3,000 to 1,700	67	17	39
Do	16	12 cm. R. F. M/94	3,000 to 1,700	33	25	30
Do	30	57 mm. R. F.	3,500 to 2,000	63	31	42
Torpedo cruiser	4	12 cm. R. F.	2,500 to 1,800	40	30	20
Do	8	57 mm. R. F.	3,000 to 1,800	35	10	23
First-class gunboat	2	15 cm	2,800 to 900	30	30	30
Do	2	12 cm	2,800 to 900	60	0	30
Do	4	57 mm. R. F.	2,800 to 900	40	30	35

It is unnecessary to add that the firing took place on the open sea.

The competitive firing of the Stockholm division took place July 14, 1899, outside of Stockholm Harbor. The target consisted of the old hulk of a small bark; during the firing the target was partly obscured by a low rock lying opposite it. The results are shown in the following table:

Class of ship.	Guns.		Distance.	Per cent of hits.		
	Number.	Caliber.		Maximum.	Minimum.	Mean.
First and second-class battleships and first-class gunboat.	2	Heavy	2,800 to 2,100	67	33	50
	6	Medium	3,000 to 1,300	50	30	37
	10	57 mm	3,000 to 1,100	80	40	70
	8	25 mm. machine	1,600 to 1,100	73	15	50

In conclusion we will mention the results of a competitive firing of the coast squadron in the year 1898 outside of Stockholm Harbor. There was some swell during the firing, and the weather was very unfavorable. The results were as follows:

Class of ship.	Guns.		Distance.	Per cent of hits.		
	Number.	Caliber.		Maximum.	Minimum.	Mean.
First-class battleship	6	25 cm. gun	2,600 to 1,200	50	20	40
Do	8	12 cm. R. F. gun	2,600 to 1,200	50	5	28
Do	4	15 cm. gun	1,200 to 2,000	92	92	92
Do	21	57 mm. R. F. gun	2,600 to 1,200	92	50	78
Torpedo cruiser and first-class gunboat.	1	Heavy	1,600 to 1,400	67	67	67
	7	Medium	1,800 to 1,200	37	30	35
	10	Light	1,800 to 1,200	90	23	35

The target in this case was a battleship section 3 x 8 + 3 x 15 m.[1]

Considering that in all the target practice referred to, the targets were comparatively small and that practice ammunition was used for all the heavy and medium guns, in which case the trajectory, as is well known, is not nearly so flat as it is when service ammunition is used, the results may be considered good.

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[1] These figures are given as they appear in the original. Their meaning is not clear.—O. N. I.

In order to make the target practice as instructive as possible it would seem, however, that the targets should more nearly represent those we have to deal with in battle than has hitherto been the case, and should therefore be towed targets, which, in view of the great expense occasioned by the consumption of ammunition, would be well justified.

It would also be expedient to consider the advisability of limiting the length of time for the firing of rapid-fire guns in order that a better idea may be gained of the rapidity of fire developed. This is done in the English navy, where one minute is the maximum length of time allowed for each passage with rapid-fire guns.

TORPEDO-FIRING TRIALS.

During torpedo-firing trials recently held in France, in which the floating target was towed by the steamer *Cyclone* with a cable 230 meters long, at a speed of 10 knots, a torpedo launched from the *Flibustier*, at a distance of 500 meters, deviated so much from its course that it passed in front of the *Cyclone*, while a second torpedo struck the *Cyclone* in the bow, causing a leak.

The various recent improvements introduced to keep the torpedo on a straight course, among the most notable of which are the Obry and Kaselowsky devices, have gone a long way to improve its accuracy, but it can not as yet be regarded as a weapon of precision.

SMALL ARMS.

That the modern small-bore magazine rifle, using smokeless powder, has not yet passed the experimental stage is shown by the fact that Germany, France, England, Portugal, and Japan are either making or contemplating changes in their service weapons. The recent Spanish-American and the present Boer wars have demonstrated the limit of its effectiveness and the necessity for a further increase in its efficiency. The war now going on is the first serious conflict in which white men have been opposed to one another using muskets of such high power, and the tactical and mechanical lessons which are being drawn from it, in so far as relates to this subject alone, are of great value.

The new German infantry rifle, which is being distributed, is of the same caliber and uses the same ammunition as the one now in general use and is simply an improved Mauser. This substitution of the new rifle for the old will cause no disturbance, as care is being taken that the same division of troops will use only rifles of the same construction. As modern rifles wear out rapidly, making renewals necessary at intervals of from four to five years, it is estimated that in a comparatively short time the entire German army will be equipped with the new weapon. The essential improvements in the new rifle, which is known as model 88/97, consist in a more effective hand protection for the barrel; a new sight; a more practical arrangement of the magazine, the cartridge frame being replaced by the so-called clip; a new form of bayonet (secured to the stock instead of to the barrel as heretofore); and the number of grooves has been increased from four to six, and the profile of the rifling changed to facilitate cleaning. Special devices have been provided to prevent double loading, the escape of gases and discharge before the barrel is entirely closed. These changes have been made with a view to removing the objectionable features which have become apparent in the practical use of the rifle.

The barrel mantle of the old model did not afford sufficient hand protection, as the heat developed by rapid firing is transmitted to it through the intervening stratum of air. This has been replaced by a wooden casing of the forward barrel, which affords better protection to the rifleman's hand. The tactical value of the piece has been increased by a modification of the sighting device. In the old model, even for comparatively short distances, the sight flap had to be raised, and the aiming done through the longitudinal slit between the two shanks of the bar. This greatly restricted the field of view. In the new device the bar is raised gradually, upon a steplike support, and a better field of vision is afforded for the most important ranges. In the former magazine the five cartridges lay one above the other, so that the box for their reception projected considerably beyond the stock. This interfered with the convenient handling of the rifle and made it particularly difficult to shoulder. Besides, the magazine was open at the bottom to allow the empty cartridge frame to drop out, thus permitting dampness and dirt to penetrate into the interior of the loading mechanism. In the new model the cartridges are seated in a clip, from which they are slipped off when loading, and lie side by side in zigzag formation. With this arrangement the magazine is closed at the bottom and its lower edge is flush with the stock. The new bayonet is triangular in shape, and is shipped underneath the barrel instead of on the side. It is thought that this method will prevent the tendency to fire too high.

Japan is substituting the new Arisaka rifle for the Murata, about 40,000 having already been issued to the troops.

France is to have a new rifle, a modification of the Lebel. The secret has been well kept and was only recently made known through a discussion of the war budget in the Chamber of Deputies. It is stated that the new arm will be issued within the next six months. No details of its construction are as yet available.

Trials have been recently made at Châlons of a new rifle invented by Captain Daudetau. The following details have appeared: Caliber, 6½ millimeters; magazine for five cartridges; barrel covered with hard wood for hand protection; cartridges of very light weight. As the data published relative to these trials are of a general and indefinite nature, no opinion can be formed of the value of the claims made for the ballistic efficiency of the weapon until the nature of the projectile and the initial velocity are known.

It is believed that since the commencement of hostilities in South Africa the English Government has learned that a great number of the British service rifles (Lee-Medfords and Lee-Enfields) are badly sighted. It appears that 250,000 new sights have been sent to the Cape to replace those upon the arms actually in use. The following have been reported as defects in the Lee-Enfield rifle: It is undersighted at all ranges; it throws to the right, and no allowance is made for "drift" with long-range sights. One seemingly well-informed writer on the subject enters so far into detail as to state that in a large number of recently manufactured rifles the fore sight has, through an error, been placed 0.023 inch to the left; and that, in consequence, these pieces at 100 yards shoot 7½ inches to the right of the point of aim.

Colonel Lockyer, chief inspector of small arms at Enfield Lock, has recently produced a carbine the range and accuracy of which are equal to those of the Lee-Enfield, and it weighs 2 pounds less. It has a long triangular bayonet, with the same handle as the old sword bayonet.

The new Lee Straight-Pull submitted to the British War Office is of particular interest to us, as it is an improvement upon our 0.236-inch naval rifle. The new arm has fewer loose parts about the breech, an improved extractor, and a new form of clip. The latter is stamped from a single piece of steel and grips the cartridges simply and effectively. Its caliber is 0.256 inch, the same as the Mannlicher. It is heavier than our piece, but lighter than the Lee-Enfield. It is stated that its point-blank range is between 600 and 700 yards, while at 1,000 yards the trajectory rises only 24 feet.

An Austrian patent to convert the Mannlicher rifle into a semi-automatic weapon, by means of the recoil, has recently appeared. In brief its action is as follows: The breech is supplemented by a tubular guide containing a spring, of which one end abuts against a pivoted plate and the other against a shoulder on the breechblock. The spring is compressed by the recoil, and immediately returns the breechblock to its closed position.

Ferdinand Ritter von Mannlicher has patented a pistol which automatically loads itself after each discharge.

Captain Cei-Rigotti, of the Italian infantry, has recently patented an automatic attachment which can be readily applied to the Mauser or the Parravicino-Carano, the present Italian rifle. It consists of four pieces, which comprise an ejector and a lever for forcing the new cartridge into position. Both ejector and lever are operated by the gas which escapes from a tiny hole near the end of the barrel into a chamber below. The gas affects alternately the ejector and lever. It is claimed that, with a weapon thus modified, 15 rounds per second can be fired without taking the rifle from the shoulder. The mechanism is provided with a cut-off, so that single shots may be fired. Captain Cei-Rigotti has sold the right to manufacture his mechanism to an Italian company.

Portugal very recently appointed a committee to select a new rifle for its infantry. After narrowing the choice down to the Mauser and the Schönauer (Steyr), it decided in favor of the latter. The report states that the weapon was selected on account of its simplicity, reliable functioning of the breech mechanism, and long range (800 meters more than the Mauser), which advantages, in the opinion of the committee, are not compensated for by the greater ease with which the Mauser can be loaded. The caliber of the new rifle is 6.5 millimeters; its weight, 3.8 kilograms; the weight of the bullet, 10.2 grams; and the initial velocity, 725 meters.

At the Royal Norwegian School of Gunnery at Tärningmoen, interesting experiments were recently made with snow walls, in place of earthworks, as a protection against small-arm fire. Walls were constructed of newly fallen snow, which consequently does not pack, and others of partly melted snow, which had thus attained its maximum density. The firing was done at ranges of 50, 120, 360, and 800 meters, respectively. The results of all the experiments were the same, with only slight differences. Six and one-half millimeter projectiles perforated the snow banks to a depth of from 80 to 90 centimeters, in exceptional cases 96 to 98 centimeters. There was little deformation of the projectiles; the greatest was noticeable in projectiles fired at the longer ranges. In no case did a bullet penetrate entirely through a snow wall of 1.20 meters thickness.

These results appear the more remarkable as the Norwegian army rifle has shown surprising penetrative power. It may be predicted that in case of a winter campaign the employment of trenches and walls built of snow would acquire considerable importance in northern countries.

That the stopping power of snow may be fully realized, the following extracts from a report of recent experiments at the Springfield Armory with a 0.30-caliber magazine rifle with service ammunition (initial velocity 2,000 foot-seconds) are given.

In targets placed at 53 feet, the following perforations were obtained:

Iron boiler plate, 0.4 inch thick, backed. Penetrated.

Iron boiler plate, 0.468 inch thick. Penetrated.

Same plate, backed. Penetrated 0.46 inch and bulged plate at back.

Iron boiler plate, 0.566 inch thick, backed. Penetrated 0.255 inch.

Soft steel plate, 0.2 inch thick, backed. Penetrated.

Seasoned oak across grain, exceptionally hard and tough. Penetrated 20.7 inches.

White-pine target of 1-inch boards, spaced 1 inch apart. Penetrated 45.8 inches of pine.

At 500 yards range, in the same target, the penetration for the 0.30-caliber rifle was 19.85 inches of pine; for the 0.30-caliber carbine, 17.96 inches; and for the 0.45-caliber Springfield rifle (lead bullet, 500 grains), 12.85 inches.

At 1,000 yards range, in the same target, the penetrations in pine were: 0.30-caliber rifle, 11.44 inches; 0.30-caliber carbine, 11.22 inches, and 0.45-caliber Springfield, 8.44 inches.

AUTOMATIC FIREARMS.

Experts seem to believe that the automatic firearm is the weapon of the future, and that ere long it will largely take the place of those in general use. As the magazine rifle was at first looked upon with disfavor, so it was with the automatic. That the latter system is growing in popularity is shown by the fact that the German and Italian Governments have already adopted a pistol of this type. Notwithstanding the arguments about the impossibility of "ammunition supply" and "control of fire," the peculiar advantages of the arm under certain conditions have forced its recognition.

The following description of Paul Mauser's automatic rifle is given in full:

The principal object of this invention is to construct a firearm which can be fired normally at a prearranged low rate of fire and which can quickly be changed on the word of command and at a critical stage of an action so as to convert it into a rapid-fire, automatic, or self-loading firearm.

In the drawings fig. 1 is a side view of the firearm. Fig. 2 is a side view of the frame from the right. Fig. 3 is a side view of the frame from the left. Fig. 4 is a longitudinal section through the lock and magazine, showing the breech closed and the weapon discharged. Fig. 5 is a sectional plan view of the parts shown in fig. 4. Fig. 6 is a plan view of the said parts. Fig. 7 is a cross section taken on the line I I in fig. 4. Fig. 8 is a cross section taken on the line II II in fig. 4. Fig. 9 is a section similar to that shown in fig. 4, but shows the breech open and the hammer cocked. Fig. 10 is a sectional plan view of the parts shown in fig. 9. Fig. 11 is a partial sectional plan view of the lock, showing the parts adjusted for rapid firing. Fig. 12 is a cross section taken on the line III III in fig. 9. Figs. 13, 14, and 15 are end views of the safety catch, showing it in position for single loading, rapid firing, and locking, respectively. Fig. 16 is a longitudinal section of portions of the lock, showing the hammer catch engaging with the hammer. Fig. 17 is a plan view of the hammer catch. Figs. 18 and 19 are detail views of the lock frame. Figs. 20, 21, 22 are detail views of the lock frame and barrel catch. Figs. 23 and 24 are detail views of the firing mechanism, showing the hammer in its two positions. Fig. 25 shows detail views of the sear. Fig. 26 shows detail views of the sear pawl. Fig. 27 shows detail views of the barrel catch.

The barrel a is slidable longitudinally in the stock b, and b' is a removable cover mortised to the stock b over the barrel and secured by rings b^2 b^3 and a cap c' on the frame c. The front-end portion of the barrel carries a sight a'.

The breech-bolt receiver a^4 is screwed to the rear-end portion of the barrel, and a^2 are locking dogs pivoted to the receiver by pivots a^3 and engaging with recesses in it and in the breech bolt d when the breech is closed by the said bolt, as shown in figure 5. The dogs are provided with projections a^{22} in front of their pivots and projections a^{23} behind their pivots. A magazine case or frame c is secured to the stock and is provided with shoulders c^{10} and c^{11}.

When the receiver and barrel are moved forward the projections a^{23} strike the shoulders c^{11} and pass under them, so that the breech bolt is locked to the receiver, as shown in fig. 5. When the receiver and barrel are moved rearward the projections a^{22} strike the shoulders c^{10}, and the breech bolt is released from the receiver and is permitted to slide back in it, as shown in fig. 9. The breech bolt is pressed forward to close the breech by means of a spring d^7, mounted on a spring holder d^6 and arranged on one side of the breech bolt.

The breech bolt slides longitudinally in the receiver and d' is the firing pin which slides longitudinally in the breech bolt. A spring d^2 inside the front-end portion of the breech bolt engages with a screw thread on the firing pin and retracts the firing pin and prevents it from projecting prematurely from the breech bolt. This spring slides back and forth with the said pin when the pin is taken out or replaced in the breech bolt. The spring is less liable to become lost when the firearm is taken apart and does not become stuck in the breech bolt and require special appliances for extracting it.

A key d^4 engages with slots in the breech bolt and firing pin and couples the said parts during the loading movements of the weapon. The key is pressed down by a spring d^3, and its projecting head d^5 bears against the shoulder d^{16} on the firing pin. The bottom of the key is inclined, and as the breech bolt is moved forward the bottom of the key strikes the projection c^5 on the lock frame, which raises the said head clear of the shoulder and permits the firing pin to be driven forward in the breech bolt by the hammer against the pressure of the spring d^2.

A breech-bolt slide a^5 is arranged in a slot in the right-hand side of the receiver a^4 and is provided with a knob a^6 for sliding it back and forth. The said slide is provided with a projection a^{21}, which engages with a shoulder d^8 on the breech bolt. An automatic catch a^{10} is pivoted to the said slide by a pin a^9 and is provided at its rear part with a ratchet tooth a^{11} and a tappet a^{12}. A push pin a^8 is slidable in the knob against the pressure of a spring a^7, and the said push pin is operatively connected to the front end of the catch a^{10}. The catch is set so as to adapt the weapon for rapid firing or for single firing. When the tooth a^{11} is arranged in the path of the shoulder d^8, as shown in figs. 5 and 10, the breech bolt is arrested each time it is driven backward, and must subsequently be released by pressing the push pin, thus timing the weapon for single firing. When the said tooth is arranged out of the path of the said shoulder, as shown in fig. 11, the breech bolt is not arrested, and the weapon is adapted for rapid firing. The adjustment of the catch is effected by a safety catch f^4, which is pivoted or screwed on a pin f^3 projecting from the end plate f of the receiver. The end plate f is provided with projections which engage with grooves f' on the receiver, and it is held in position by a catch $f'*$.

The safety catch has a disk f^5, provided with two deep notches f^6 and f^8, and a shallow notch f^7 between the deep notches, for the tappet a^{12} to engage with. When the safety catch is turned to the right, as shown in figs. 10 and 13, the tappet enters the deep notch f^6, and the breech bolt is arrested at the end of each rearward movement. When the safety catch is placed in its middle position, as shown in figs. 11 and 14, the tappet engages with the shallow notch and the breech bolt is not arrested. When the safety catch is turned to the left, as shown in fig. 15, the tappet engages with the deep notch f^8 and the breech bolt is arrested, as before, and, in addition, a projection f^9 on the catch engages the inclined end portion g' of the hammer catch g and thrusts it forward. The projection also enters a groove in the frame c.

The hammer h^4 is pivoted in the lock frame h, which is supported in the frame c. The hammer catch slides in a lug g^5 on the under side of the receiver, and is provided with a point g^3, which engages with a notch h^{10} in the hammer when the hammer is cocked and the hammer catch is pushed forward. A spring g^2 is provided for retracting the hammer catch. When the hammer catch and the safety catch are operated, the hammer is locked to the receiver and the receiver is locked to the frame c, which is secured to the stock of the weapon, so that the barrel can not slide.

In order to retain the barrel (together with the receiver) in its rearward position

Fig. 1.

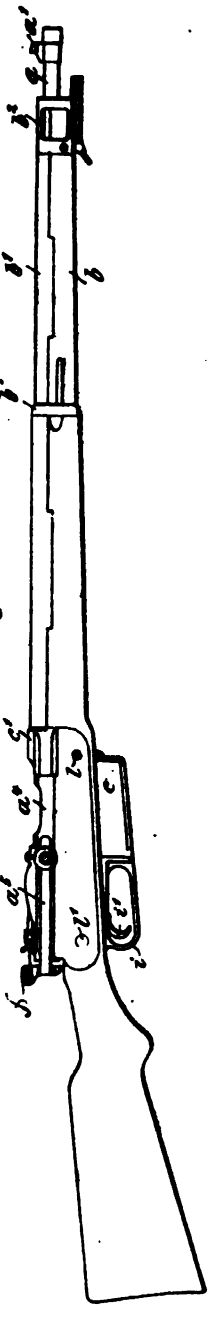

Fig. 3.

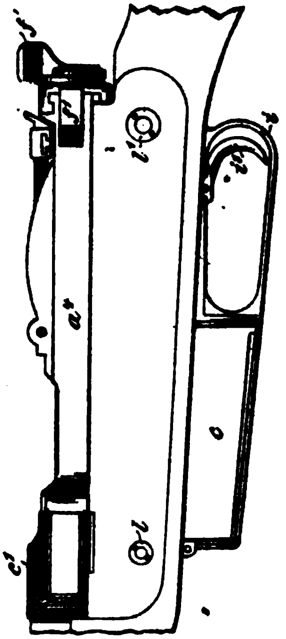

Fig. 2.

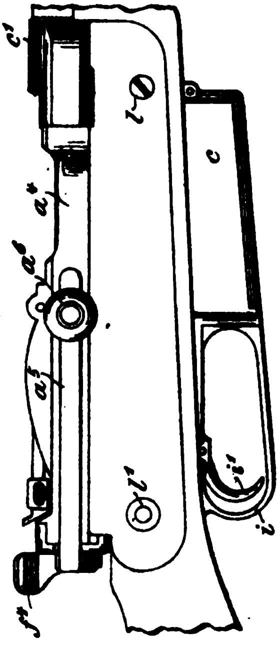

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Fig. 4.

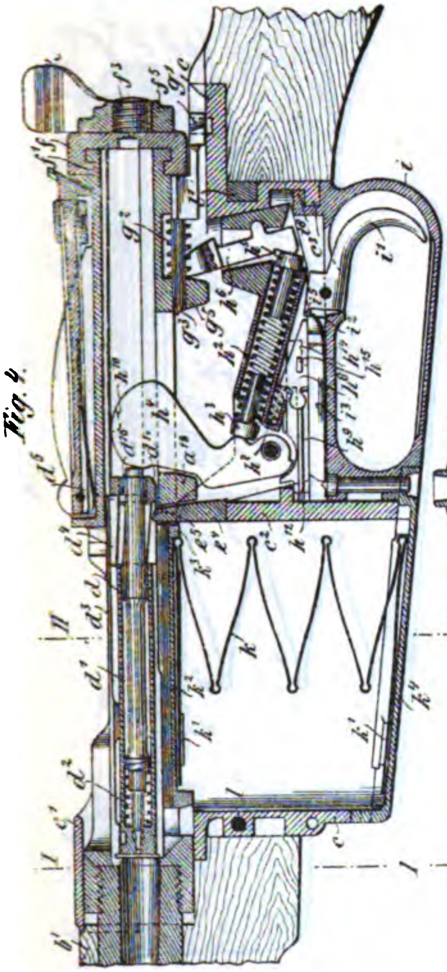

Fig. 5.

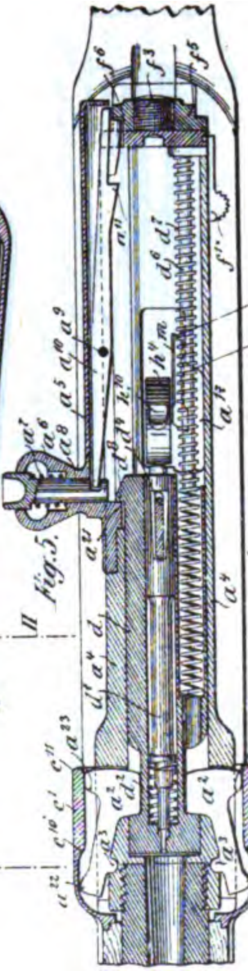

Fig. 6.

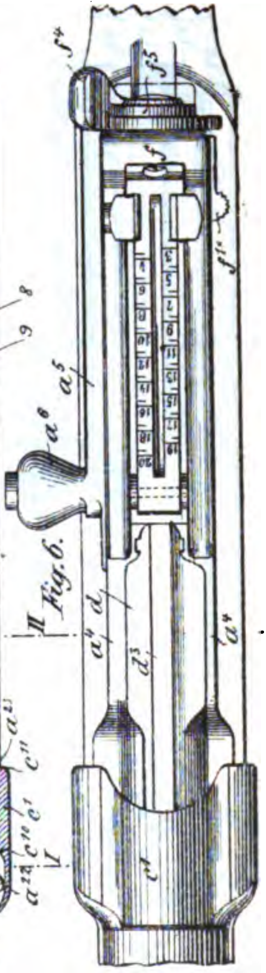

Fig. 7. (I-I)

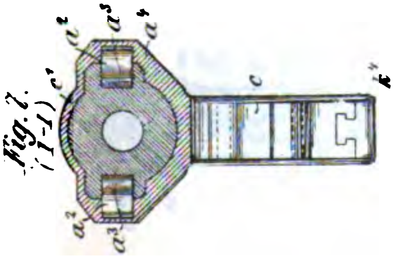

Fig. 8. (II-II)

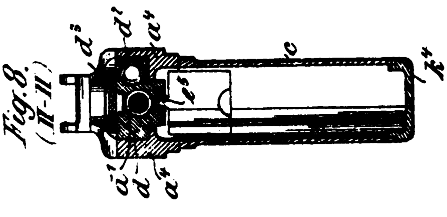

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Fig. 9.

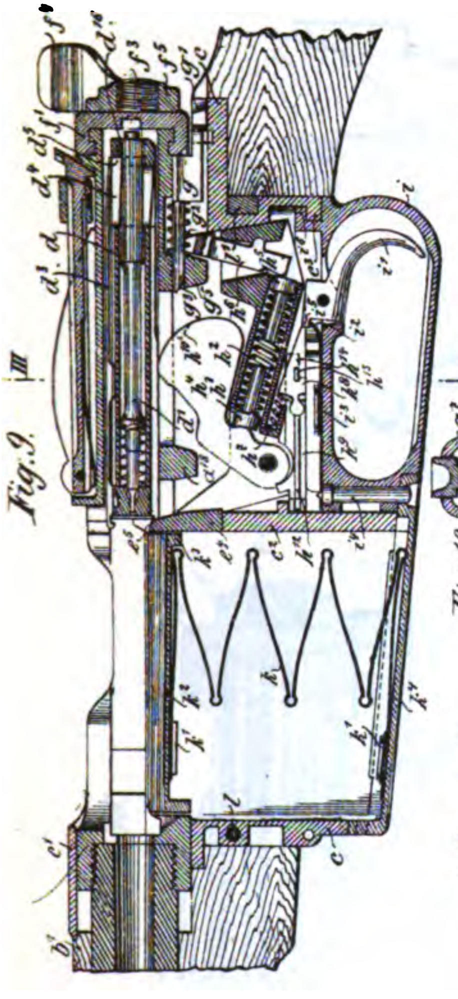

Fig. 10.

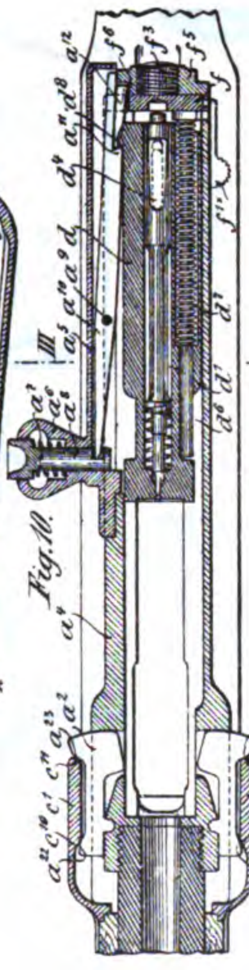

Fig. 11.

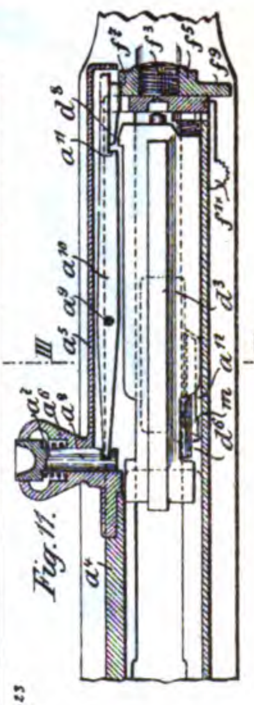

Fig. 15.

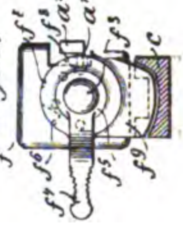

Fig. 12.
(III-III)

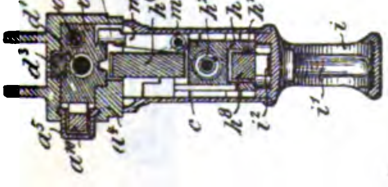

Fig. 13.

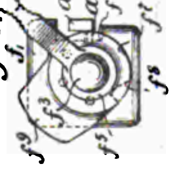

Fig. 14.

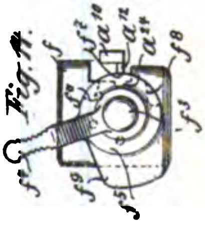

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Fig. 16.

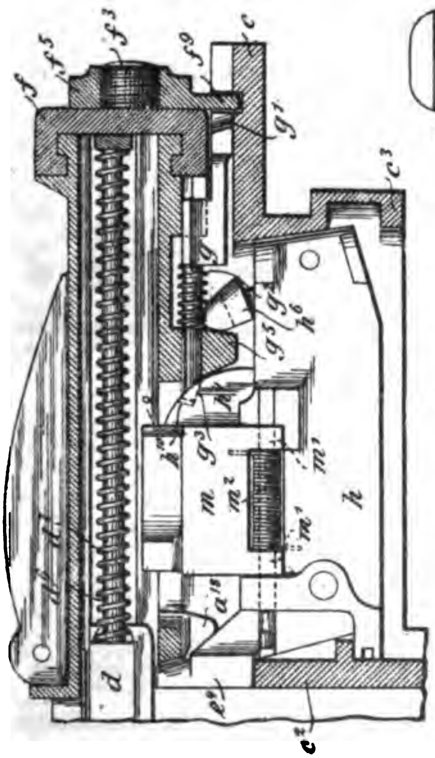


Fig. 17.

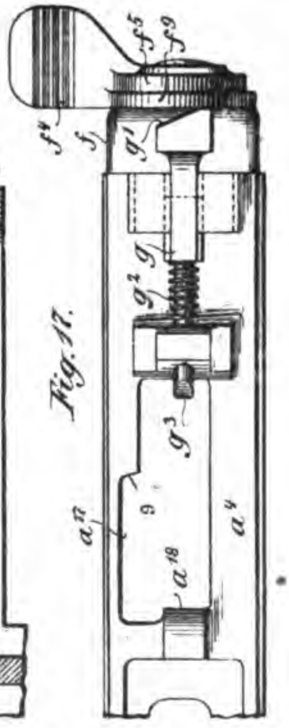


Fig. 18.

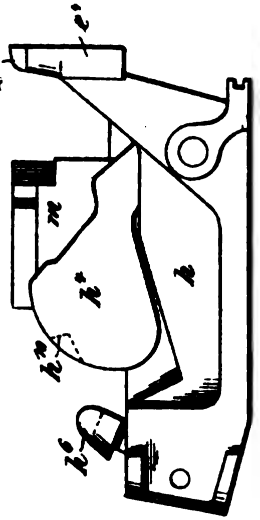
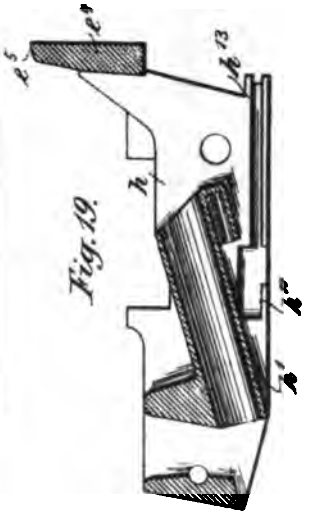


Fig. 19.



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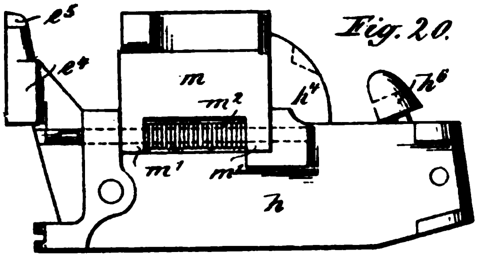


Fig. 20.

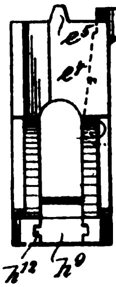
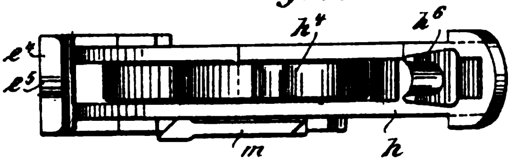


Fig. 21.

Fig. 22



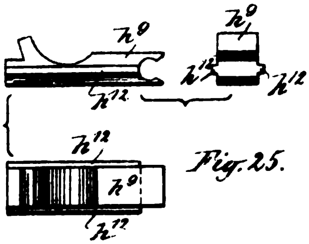
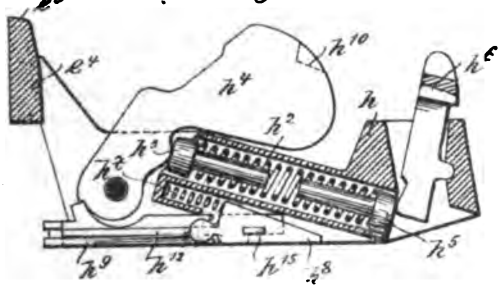


Fig. 25.

Fig. 23.



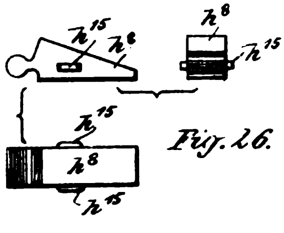


Fig. 26.

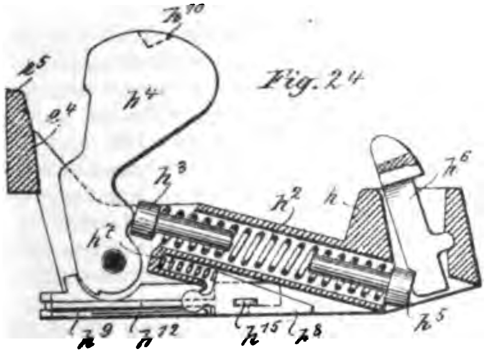


Fig. 24

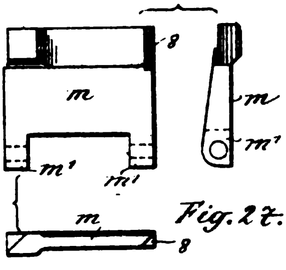


Fig. 27.

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independent of the safety catch, and after firing a shot, until the breech bolt has been moved forward and has pushed the cartridge at the top of the magazine into the barrel, a barrel catch m (*see* fig. 16) is pivoted on a pin m', arranged longitudinally in the lock frame h. This catch is moved laterally outward into a recess a^{17} in the receiver by its spring m^2 when the receiver is moved backward with the barrel. When the breech bolt is retracted, it locks the catch in the recess, as shown in fig. 12.

When the breech bolt slides forward into the position shown in fig. 5, it moves past the barrel catch m, which is then pushed laterally out of the recess by the receiver as it slides forward after the breech bolt has completed its forward movement. Inclined surfaces 8 and 9 are provided on the catch m and on the receiver at one end of the recess, so that the receiver-operating mechanism overcomes the pressure of the spring m^2.

A pusher h^6 is pivoted in the lock frame h, and its upper end bears against the lug g^5 and operates to push forward the receiver and barrel. A guide chamber h' for the spring and pistons is arranged in the lock frame in an upwardly and forwardly inclined position, and contains a spiral spring h^2. A piston h^3 engages with one end of the spring and operates against the hammer, and a piston h^5 engages with the other end of the spring and operates against the pusher. The sear spring h^7 is arranged in a chamber under the chamber h'. The sear spring bears against the sear pawl h^8, which is articulated to the sear h^9. The sear has two guide ribs h^{12}, which slide in grooves h^{13} in the lock frame (*see* fig. 19), and h^{14} are lugs in rear of the said grooves for the lugs h^{15}, which project from the sides of the sear pawl, to slide on.

The trigger i' is pivoted to the trigger guard i, and is provided with a nose i^5. This nose is normally pushed upward and rearward by the trigger spring i^2, which is held against the top of the trigger guard by lugs i^3 projecting from the frame c. The trigger spring also holds the retractible bolt i^4 in engagement with the bottom plate of the magazine.

The magazine is arranged under the breech. The feed plate k^2 and the bottom plate k^4 are provided with lugs k' near their front ends, and k is a zigzag spring arranged in the rear part of the magazine and provided with forwardly projecting end portions which engage with the lugs k'. When the spring is used, the rear ends of the cartridges are raised higher and with greater pressure than their front ends, which is very desirable in a rapid-fire weapon, as it insures the rear end of each cartridge being brought to its position in the path of the breech bolt before the breech bolt strikes it.

The magazine frame or case c is connected to the stock by bolts or screws $l\ l'$, and the front portion c^4 of the lock frame is placed over the rear wall c^2 of the magazine. The rear nose i^6 of the trigger guard engages with a projection c^3 on the frame c, and all the parts are finally secured by inserting the bottom plate of the magazine.

The weapon is operated as follows: When required for rapid firing, the safety catch is placed in its middle position and the breech bolt is drawn back by the knob a^6 until its front end is engaged by the stop k^3 on the rear end of the cartridge-supply plate of the magazine, which has risen in front of the breech bolt under the action of its spring k, and the knob is pushed forward to its original position. In drawing back the breech bolt the hammer is cocked partly by the projection a^{18} on the breech bolt slide and partly by the shoulder $d'*$ on the breech bolt. The magazine is then filled with cartridges by means of a cartridge holder of approved construction. When the empty holder is removed from the magazine, the breech bolt is pressed forward by its spring d^7, and the receiver and barrel are pressed forward by the pusher h^6, so that the top cartridge is pushed into the barrel and the weapon is in a proper condition to be fired. The weapon is fired by the trigger, which presses the sear pawl and sear forward by means of its nose. The hammer is disengaged when the sear is pushed forward and is then operated by its spring h^3, so that it strikes the rear end of the firing pin and drives it against the cap of the cartridge, so that the cartridge is exploded. The barrel and breech bolt first recoil together. The locking dogs (by the lugs a^{22} engaging the shoulders c^{10}, which forces out their rear ends) then unlock the breech bolt, which continues to move back under its required momentum, and the barrel catch enters the recess a^{17} and temporarily locks the barrel and receiver to the stock. The empty cartridge shell is ejected in the usual manner when the breech bolt is driven rearward. The rearward motion of the breech block also cocks the hammer, which is held cocked by the sear. The breech bolt having completed its rearward movement is at once pushed forward by its spring, and as soon as the breech bolt is clear of the barrel catch the receiver and barrel are pushed forward by the spring-operated pusher, which overcomes the pressure of the barrel-catch spring. The weapon can be fired as rapidly as the trigger can be pulled, the speed depending upon the skill of the operator.

When for tactical reasons the rate of firing is to be approximated to that of a single-firing weapon, the safety catch is placed in the position shown in fig. 13. The forward motion of the breech bolt is now arrested at the end of each recoil, and the breech bolt can not move forward until it has been released from the pivoted catch by pressing the push pin a^8. As it takes a certain amount of time to operate the push pin before pulling the trigger, the rate of firing is diminished to a substantially predetermined extent.

When blank cartridges are fired, the breech bolt must be retracted by hand.

GUNS AND MOUNTS.

AUTOMATIC MACHINE GUNS.

Under this head are classed weapons mounted upon field carriages, tripod and quadrupod mounts or fixed stands, in which the operations of loading, firing, and extracting the empty cartridge cases are successively performed automatically by a continuous and regular action of the breech mechanism. Such a gun may be of any caliber, may have one or more barrels, and should be so constructed that it may be worked by hand.

It is safe to say that no one gun of this nature has demonstrated any marked degree of efficiency over the rest of its class.

France prefers the Hotchkiss type and a new model is now being issued. The new arm, which consists in all of thirty pieces, easily taken apart and put together again, is formed of a single barrel in front of a receiver, the mechanism of which is said to be very simple. The cartridges are attached to a revolving brass band, which works automatically, each shot that is fired bringing the next one into position. The gun is provided with a butt, similar to that of an ordinary musket, which the pointer rests against his shoulder. Its total weight, without supports, is 53 pounds. Two men are required to work the gun, one to load and the other to point and fire it. It is claimed that from 500 to 600 rounds per minute can be discharged. Various types of mounts are to be used with this gun. For mountain service, a folding tripod, to be carried on an animal's back, is used; for field service, it is mounted upon a wheeled carriage, having a shield and limber; while on board ship it is to be placed upon the usual pillar mounting.

In Sweden a modification of the Nordenfelt by Captain Bergmann of that country has attracted the attention of its ordnance experts. It is claimed that this gun is strongly built, its parts are few and quickly replaced, and it easily shifts from automatic to hand fire. The barrel is inclosed in a water jacket. The cartridges are carried in flexible metallic bands contained in boxes. Rate of fire (claimed) 600 shots per minute.

Particulars are gradually becoming known of a new automatic gun of the Maxim type recently issued for trial to the German chasseurs. The caliber is the same as that of the infantry rifle and the same ammunition is used. The barrel, to prevent overheating, is inclosed in a water jacket. The gun is carried by two men, but one is sufficient to train and tend the piece. Two men carry boxes containing small wheels around which the cartridge belts are wound. During rapid fire the belts unroll with great rapidity; each holds 250 cartridges. This gun is designed for the purpose of keeping under a hot fire a small and well defined piece of ground. The maximum rate of fire (claimed) is 600 rounds per minute. It can be adapted to a slow fire of 50 rounds.

The English in South Africa are using both Maxim (of a different type from the above) and Colt automatic guns. At Chieveley, on February 13 last, two Maxim guns are reported to have jammed and it was necessary to take them out of action. The Colt guns, during this engagement, are reported to have worked well. This last weapon, on the Dundonald carriage, seems to have passed a satisfactory test.

In Volume XVIII of General Information Series it is stated that the failures of the Colt automatic during the Spanish-American war led our War Department to institute a competitive trial of weapons of this class. The guns entered for trial were the Hotchkiss, Colt, Maxim, and Carr. All are said to have given excellent results, but the Colt is unofficially stated as having been the favorite. The Carr gun, about which very little is generally known, was placed upon a tripod which was found to be too light, and it is understood that further tests will be given it. This gun weighs only 12 pounds and is fed from a drum containing 450 cartridges.

In view of the fact that neither the results of these tests nor the conclusions of the board that conducted them have been published, the following detailed report of competitive trials conducted in Sweden with automatic guns becomes of peculiar interest:

FIRING TRIALS WITH AUTOMATIC GUNS AT VAXHOLM AND OSCAR-FREDRIKSBORG, SWEDEN, SEPTEMBER 25 TO 27, 1899.

[Translated from the Swedish *Artilleria Tidskrift, No. 5. of 1899.*]

The following types of automatic guns took part in the program laid down for these firing trials: 8-millimeter Nordenfelt automatic gun; 8-millimeter Madsen automatic gun; 8-millimeter Maxim automatic gun; 6.5-millimeter Maxim automatic gun.

The last-named two belonged to the Stockholm Ordnance factory. The 6.5-millimeter Maxim gun was identical with the 8-millimeter Maxim, with the exception of three parts—namely, the barrel, the cartridge chamber, and the cartridge-feeding apparatus.

The object of these trials was to compare the different automatic guns as to their accuracy of fire, effect of fire, sensibility to dampness and dust, durability and proper functioning.

During the trials the automatic guns rested in the following mounts:

The Nordenfelt in a folding tripod mount with elevating device, and apparatus for keeping the gun, when trained, in position during the firing.

The Madsen gun, part of the time in a tripod mount and part of the time in a kind of casemate carriage which, during firing, was secured by means of screws to the stump of an oak tree. This carriage had adjusting screws by means of which the gun, being given the required elevation, could be kept in position; it also had a device for limiting the lateral training.

The Maxim guns rested in field carriages with handwheels for elevating and training, and were equipped with devices for limiting the lateral training and for obviating the inclined position of trunnions.

The following ammunition had been provided for the trials: 10,000 8-millimeter service cartridges M/89, and 3,500 6.5-millimeter service cartridges M/94. The former had Swedish, the latter German, cartridge cases.

All the ammunition had been manufactured in 1897. Four thousand eight hundred and seventy of the 8-millimeter cartridges and 1,440 of the 6.5-millimeter cartridges were used during the trials. Before the beginning of the trials all the cartridges the cases of which were cracked were taken out, so that only perfect ammunition was used in the seven series which constituted the competitive firing trials.

Prior to the commencement of the firing, the men who were to handle the guns were drilled by the representatives of the respective gun factories in serving the guns (pointing and loading), taking apart the breech, replacing the firing pin and spring, etc., and during the firing each of the guns was served by one and the same man.

In accordance with the program, Series I and II were to test the accuracy of fire at ranges of 200 and 400 meters, respectively. Each series consisted of 20 rounds of single fire and 20 rounds of rapid fire. Accurate pointing was required in both series.

A wooden target, 3 by 2 meters, divided into squares, was used. Before each series a certain number of trial rounds were allowed. Although the target against which the firing was done was considerably larger than those used by the infantry when firing with rifles resting in tripods, not all of the 20 rounds fired hit the target.

The results of these two series are shown in the following table:

	Series I, 200 meters.				Series II, 400 meters.			
	a—Single fire.		*b*—Rapid fire.		*a*—Single fire.		*b*—Rapid fire.	
	Divergence.							
	Vert.	Lat.	Vert.	Lat.	Vert.	Lat.	Vert.	Lat.
	cm.	*cm.*	*cm.*	*cm.*	*cm.*	*cm.*	*cm.*	*cm.*
8-mm. Nordenfelt	2.5	2.3	5.7	4	3.8	7.5	7.5	6.8
8-mm. Madsen	5.4	3.4	7.5	5.2	(?)	(?)	8.3	11.2
8-mm. Maxim	3	1.8	14.5	6.7	6.5	4.8	(?)	(?)
6.5-mm. Maxim	7.8	9.5	12.4	15.4	(?)	(?)	(?)	(?)

The Madsen automatic gun is not adapted for rapid fire; hence Series I*b* and II*b* in this case consisted of lively single fire, which was as rapid as was possible, considering the necessity of pulling the trigger for each round.

By reason of the different mounts used, the results shown in the table do not give an entirely correct idea of the relative merit of the different guns on the question of divergence.

Relative to the 8-millimeter Maxim, it was ascertained that in rapid fire the cones of divergence lie lower than in single fire.

In accordance with the program, Series III and IV were fired at 400 meters. The wooden target, 30 by 1.8 meters, was divided into 50 squares.

Before the beginning of Series III the guns fired several trial shots. The crews were also drilled in replacing the cartridge band, and were instructed in the manner of handling the breech mechanism in case it should fail to function owing to missfires, jamming of cartridge case, defective ammunition, etc.

The following table shows the results of these two series as to hits:

	Series III, ¼ minute.				Series IV, 3 minutes.			
	Number of rounds.	Number of hits.	Per cent of hits.	Squares hit.	Number of rounds.	Number of hits.	Per cent of hits.	Squares hit.
8-mm. Nordenfelt....	108	95	87.9	41	410	328	80	49
8-mm. Madsen	47	26	55.3	20	125	35	28	18
8-mm. Maxim........	70	40	57.1	27	1,087	572	52.6	48
6.5-mm. Maxim......	148	101	68.2	41	600	308	51.3	48

During the firing the following interruptions were experienced:

IN SERIES III.

With the 8-millimeter Maxim gun: Twelve seconds at beginning of firing, owing to the fact that the mechanism stuck and the cartridge-feeding apparatus did not function properly, because the cartridge belt had not been inserted correctly. During the remaining three seconds the gun could not be gotten ready for firing. It would have required forty seconds to put it in working order.

With the Madsen gun: An interruption of about three seconds, owing to delay in exchanging the magazine.

With the other two guns no interruptions occurred in this series.

IN SERIES IV.

With Nordenfelt gun: Three interruptions of forty-nine, six, and fourteen seconds, respectively, all due to the fact that a cartridge dropped from the belt by the rear end, while the forward end stuck transversely, thus interfering with the forward movement of the cartridge belt. At the first interruption the cartridge had become jammed in the opening designed for the cartridge belt, so that the mechanism ceased to function. The manufacturer's representative explained that the dropping out of the cartridges by the rear end was due to the fact that the belt used at the trials did not hold the cartridges as firmly as the belts ordinarily used. Three interruptions of four, three, and two seconds, respectively, due to missfires. Two interruptions of eleven and twenty-one seconds, respectively, in exchanging two cartridge belts. Moreover, the mechanism stuck six times, because the recoil spring was not strong enough to close the breech again. In a case of this kind, the same as in case of missfire, the mechanism is restored to working order by giving the hand crank one turn, which requires about a second. Total time lost as the result of the different disturbances mentioned, one minute and fifty-six seconds.

With the Madsen gun: Two interruptions of three and four seconds, respectively, in exchanging the magazine. An interruption of fifty-nine seconds, due to the fact that at the beginning of the firing the cartridge jammed in the cartridge chamber, so that the breech mechanism could not be closed. The cartridge stuck so tight that it could not be taken out by hand, but had to be pushed out from the muzzle with the cleaning rod. According to the statement of the constructor, the barrel has minimum cartridge chambers, to which the cause of the jamming of the cartridges must be attributed in this case; but during this series it happened nine times more that cartridges stuck in the cartridge chamber so that they could not be ejected automatically, but had to be taken out by hand. Total time of all the interruptions above mentioned, two minutes and twelve seconds.

With the 8-millimeter Maxim gun: Three interruptions of seven, six, and five seconds, respectively, in replacing the cartridge belt. Two interruptions of two seconds each owing to missfires. At the end of two minutes and forty-four seconds the spring of the firing-pin broke, so that the mechanism stuck fast, and the weapon could not be restored to working order during the time still remaining for this series, for it required three and one-half minutes to replace the spring of the firing-pin. Even if there had been an extra breech, no more firing could have been done during the series, as it required about fourteen seconds to replace the breech. The total time consumed by the interruptions above mentioned was thirty-eight seconds.

With the 6.5-millimeter Maxim gun: Two interruptions of six and sixteen seconds, respectively, in changing the cartridge belt. One interruption of eighty-two seconds, due to the fact that in drawing the cartridge from the belt the projectile stuck crosswise, and as a result the powder penetrated into the box of the breech mechanism. This was remedied by removing the powder. Two interruptions of five and six seconds, respectively, due to the fact that before the beginning of the firing the cartridge belt was twice handled improperly. Total time lost by the interruptions above mentioned, one minute and fifty-five seconds.

In order to test the automatic guns as to their sensibility to dampness, the breech mechanism was opened before beginning the firing and water was squirted into it with a fire engine. The box and cartridge belt were also sprinkled with water, whereupon the firing was commenced, while the squirting of water was still continued. Not one of the automatic guns suffered any disturbances during this experiment; on the contrary, all functioned perfectly.

The guns were further tested as to their sensibility to dust by sifting fine road dust into the mechanisms, having previously greased the latter. The breech was then closed, and dust was also scattered over the cartridge belts and the outside of the guns. Not one of them was affected by the dust, and the Nordenfelt and Maxim guns fired 200 and 250 cartridges, respectively—that is, the whole of the cartridge belt—without any interruption and with an even rapidity of fire.

With the Madsen gun about 50 cartridges were fired without any other interruption being experienced, except such as mentioned in former series.

The guns were further tested as to their sensibility to dampness and dust combined by first sprinkling the mechanism and cartridge belt with water and then blowing fine dust into the mechanism and on the belt, whereupon the firing was commenced.

During this experiment the Nordenfelt gun showed a perceptible decrease in the rapidity of fire after the first 30 rounds. The mechanism stuck, and had to be set in motion again by the hand crank. After that, with each revolution 4 to 5 rounds were fired at first, later 2 to 3, and finally only 1 round, after which the firing stopped. When the gun had been cleaned, which took three minutes, it was once more ready for firing; but after the first few rounds the mechanism stuck once more, and when the crank was resorted to the ramrod spring snapped. It required three minutes to replace this spring.

In the Madsen gun the cartridges jammed in the magazine and cartridge chamber; in order to restore the gun to working order, the cartridges had to be removed by hand. After that a few rounds could be fired, but the mechanism functioned with ever-increasing difficulty and finally failed altogether, as the cartridges could no longer be introduced into the cartridge chamber. It required three minutes to restore the gun to working order.

In the 8-millimeter Maxim gun the mechanism stopped after the first few rounds, the dirt preventing the cartridge-feeding mechanism from assuming its proper position. This was repeated four times during the series, and when, after this interruption, the gun was once more made ready for firing by the use of the crank, only a few rounds could be fired with each revolution. After cleaning the gun, which took five minutes, and putting on a new cartridge belt, the weapon was once more ready for firing.

In the 6.5-millimeter Maxim gun the same observations were made as to this test as in the case of the 8-millimeter gun.

In order to determine what influence cracked cartridges exerted on the different guns, cracked cartridge cases were placed in the cartridge belts in such manner that each third cartridge was defective.

In the Nordenfelt gun the defective ammunition was of no influence.

In the Madsen gun the projectiles when introducing the cartridges struck against the steep inclined plane; and the cartridge cases being cracked, the projectiles were pressed into them and the former thereby widened to such an extent that the cartridges could not be introduced into the cartridge chamber.

The 8-millimeter Maxim gun was not affected by the defective ammunition.

In the 6.5-millimeter Maxim gun, however, the projectiles dropped out of the cracked cartridge cases in several instances. This released the powder which, falling into the mechanism, caused it to stop.

The committee in charge of the trials of these different automatic guns made the following statements:

I. NORDENFELT AUTOMATIC GUN.

1. As the mechanism consists of many parts connected with each other, the proper handling of this weapon requires specially well trained and skillful men, so that when the mechanism gets out of order the cause can be promptly ascertained and easily removed. The arrangement for holding the hand crank in position after turning it is not considered perfect, as the crank does not at once assume its proper position, and it requires too much time to get it into that position.

2. The gun has at the forward end of the barrel a recoil jacket designed to give the gun sufficient recoil reinforcement. During the firing the inadequate strength of the recoil spring caused a disturbance which was difficult to overcome, because the elastic force of the spring should correspond to the force of the recoil. This feature, no doubt, constitutes a drawback to the system.

3. As the ammunition of the 8-millimeter rifle M/89 is intended to be used also for the automatic gun, the barrels of the two weapons should be of the same length. The barrel in the latter case is 110 millimeters shorter than that of the 8-millimeter rifle, probably because it has been found that with a longer barrel the automatic gun did not function properly, in spite of the recoil reinforcement.

4. The valve for the escape of the steam is in a bad position, as the escaping steam obscures the line of sight and exposes the gunner to the danger of being scalded.

5. There was no opportunity for determining whether the water jacket can be refilled during the firing and while steam is escaping, since in Series IV the number of shots was not sufficient to cause the water to boil.

6. The shape of the sights is not practical, and the front sight is too small as compared with the breech sight. The arrangement for setting the sight is good, but the spring is not strong enough to maintain the sight bar in an upright position during the firing. The sight is not movable laterally; the trials have demonstrated that this would be desirable.

7. The arrangement of the cartridge belt is not entirely faultless. The belt is made of metal, and for recharging it specially constructed tongs are required in order to restore the proper shape of the cartridge holders. The connecting links between the cartridge holders rust and break easily, being made of iron wire, and decrease the flexibility of the belt; the different parts of the belt get easily entangled and prevent the proper feeding of the cartridges. The empty cartridge belt requires too careful handling in order not to bend any part of it. The belts can not be connected with each other.

8. No apparatus is provided for inserting and charging the belts. This is deemed necessary.

9. The inclination of the bottom of the magazine is not sufficient, as it does not cause the upper part of the belt to lie in a horizontal position, and the cartridges slant downward, which causes the belt to get easily out of order and renders it difficult to replace.

II. MADSEN AUTOMATIC GUN.

1. The gun is not adapted for rapid firing, so that it can only be used for single fire.

2. Its mechanism consists of comparatively few and simple parts. The inclined plane, which is designed to introduce the point of the projectile into the cartridge chamber, is too steep, and when the cartridge case is only slightly cracked the projectile is pressed into it.

3. The opening from which the empty cartridge cases are ejected terminates just forward of the small of the stock, so that it might easily happen that it is covered up by the gunner's hand.

4. The barrel is surrounded by a steel jacket, without water, which therefore becomes easily heated, so that it may burn the gunner's hand in the handling of the weapon.

III. 8-MILLIMETER MAXIM AUTOMATIC GUN.

1. The same as in the Nordenfelt gun, the mechanism consists of many parts and therefore requires considerable knowledge and experience on the part of the person handling it. The serving of the gun, however, is greatly facilitated and simplified by the fact that there are in the breech mechanism twenty parts which can be easily exchanged.

2. As a rule this gun does not have a recoil reinforcement, but such a reinforcement has been provided so that the rapidity of fire can be increased, as has been demonstrated during these trials.

3. The poor result as to hits in the different series must be attributed to the fact that the gun moved too easily in a vertical direction during rapid firing, although it rested in a heavy and steady carriage. Perhaps this defect may also be attributed to the fact that the barrel of this gun is still shorter than that of the Nordenfelt weapon. (*See* Nordenfelt, par. 3.)

4. The committee had no opportunity for ascertaining whether the water in the water jacket can be renewed during firing and while the water is boiling, but it was found that after Series IV (three minutes) about two-thirds of the water in the water jacket had evaporated. (The jacket holds about 3 liters.) The remaining water had evaporated comparatively rapidly during the different series, so that it appears questionable whether the gun would be able to do rapid firing for three consecutive minutes without having the water jacket refilled. Without water this gun can not fire more than a few rounds of rapid fire, as the barrel when firing for any length of time becomes red hot, then bends, and finally is rendered unserviceable.

5. The sight has no lateral motion. The spring of the sight bar is entirely too weak, so that the bar shakes when in a vertical position.

6. The cartridge belt, which is made of webbing, has at each third cartridge comparatively long brass points secured to the belt with two rivets. The ends of these

points bend easily and thereby interfere with the introduction of the belt into the chamber. After being used for a certain length of time the cartridge belts were cut by the forward sharp edges of the cartridge cases.

7. Special apparatus was used for charging the cartridge belts, but care had to be taken to have the cartridges lie at equal distances in front of the belts. The belts can not be coupled together.

IV. 6.5-MILLIMETER MAXIM AUTOMATIC GUN.

The observations made by the committee relative to this gun were about the same as those made concerning the 8-millimeter Maxim, the only essential difference being that the result as to hits was better in the latter case than in the former. The 6.5-millimeter Maxim gun, moreover, becomes heated more rapidly and therefore consumes more water; besides, the projectiles get stuck in the belt more easily when cracked cartridge cases are used.

The following table contains some miscellaneous data relative to the automatic guns under consideration:

	Cartridge belt or magazine.				Maximum number of rounds per second.	Time required for—		
	Number of cartridges.	Price each.[1]	Time required for—			Cleaning mechanism.	Replacing spring of firing-pin.	Replacing breech.
			Loading belt (magazine).	Replacing belt (magazine).				
		Marks.	*Min.*	*Sec.*		*Min.*	*Min.*	*Min.*
8-mm. Nordenfelt	200	2¼	7[2]	8	7	3	2	2
8-mm. Madsen	25	....	⅓[2]	4	4	3	1.5	1⅓
8-mm. Maxim	250	2¼	7[3]	8	7	5	3.5	¼
6.5-mm. Maxim	250	2¼	5[3]	8	6	5	3.5	¼

[1] Mark=$0.238.
[2] By one man.
[3] By two men.

As to the practicability of these automatic guns employed in casemate carriages for sweeping ditches, as also on board of armored vessels and in connection with mobile defenses, the following may be stated:

I. NORDENFELT AUTOMATIC GUN.

As this gun, in the opinion of the committee, has not proved at the firing trials to be such a weapon as would be required for service in war, the committee deemed it unsuitable for the purposes above set forth.

II. MADSEN AUTOMATIC GUN.

What has been stated under "I" relative to the Nordenfelt gun applies, in the opinion of the committee, with even better reason to the Madsen weapon.

III. 8-MILLIMETER MAXIM AUTOMATIC GUN.

Although the committee ascertained at the trials that the accuracy of fire of this automatic gun is not very great and that for firing for any length of time (three to five minutes) the water jacket is not sufficiently large, the committee was, nevertheless, of opinion that this gun, in view of the good functioning of its mechanism, generally speaking, is adapted for sweeping ditches. It would be of advantage, however, if the accuracy of fire could be enhanced and the space inside of the water jacket increased or the cooling of the barrel effected by flowing water.

Concerning the employment of this gun on board of armored vessels or in connection with mobile defenses, the committee was of opinion that it is adapted for such purposes only on certain conditions, which, in the opinion of the committee, are as follows:

(1) That the accuracy of fire of the gun be increased in such manner as to make it equal to that of the same caliber infantry rifle.

(2) That for continuous fire, lasting four to five minutes, the gun be provided with a sufficiently large water jacket.

(3) That proper arrangements be made on board the armored vessel, so that during the firing the cooling of the gun can be effected by flowing water contained in a suitable receptacle.

(4) That means be devised for preventing the steam from molesting the gunners in any manner and from interfering with the training of the gun; furthermore, that the escaping steam do not betray the location of the armored vessel.

IV. 6.5-MILLIMETER MAXIM AUTOMATIC GUN.

Since the accuracy of fire of this gun is inferior to that of the 8-millimeter Maxim, and since it is affected in a higher degree than the latter by the quality of the ammunition, and, finally, since the ammunition of the 6.5-millimeter gun, as far as the cartridge cases are concerned, is not as good as the 8-millimeter ammunition, the committee was of opinion that the 6.5-millimeter gun is not suitable for any of the purposes in question.

Besides the automatic guns referred to in the foregoing report there has also been some talk of the Colt, Gardener, and Skoda automatic guns; but as no very high opinion has at any time been entertained as to their serviceability, it is not surprising that they were not included in these competitive trials in Sweden. It seems strange, however, that not a single trial has been made in Sweden of the Hotchkiss automatic gun, which has often been highly spoken of, although as yet it is said to be in service only in a few French battalions of Alpine chasseurs.

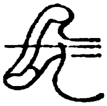
In view of the simplicity of the mechanism, which feature the Hotchkiss automatic gun shares with our infantry rifle, and the fact that it is said to be in no manner affected by dust and rain, it would seem as though it were much better adapted for use as an auxiliary field weapon for our infantry than the Maxim gun, with its complicated and difficult mechanism.

VICKERS'S 14-POUNDER 8-INCH SEMI-AUTOMATIC NAVAL GUN.

This gun, which is semi-automatic in its action, is illustrated by figures 1 to 7, inclusive.

The following is a table of the principal dimensions and some of the results obtained in trial:

Diameter of bore	3 inches.
Length of bore (50 calibers)	150 inches.
Total length of gun	161.95 inches.
Diameter of chamber	3.01 inches.
Length of chamber	27.76 inches.
Maximum pressure in chamber	16.5 tons.
Weight of charge	3 pounds 2.5 ounces.
Total weight of gun, including breech mechanism	17 cwt. 2 quarters 20 pounds.
Muzzle velocity	2,650 foot-seconds.
Muzzle energy	681 foot-tons.
Perforation of wrought-iron plate at muzzle by Gavre formula	10.2 inches.



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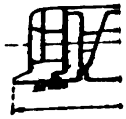
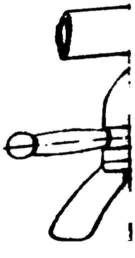


Fig.

Fig.



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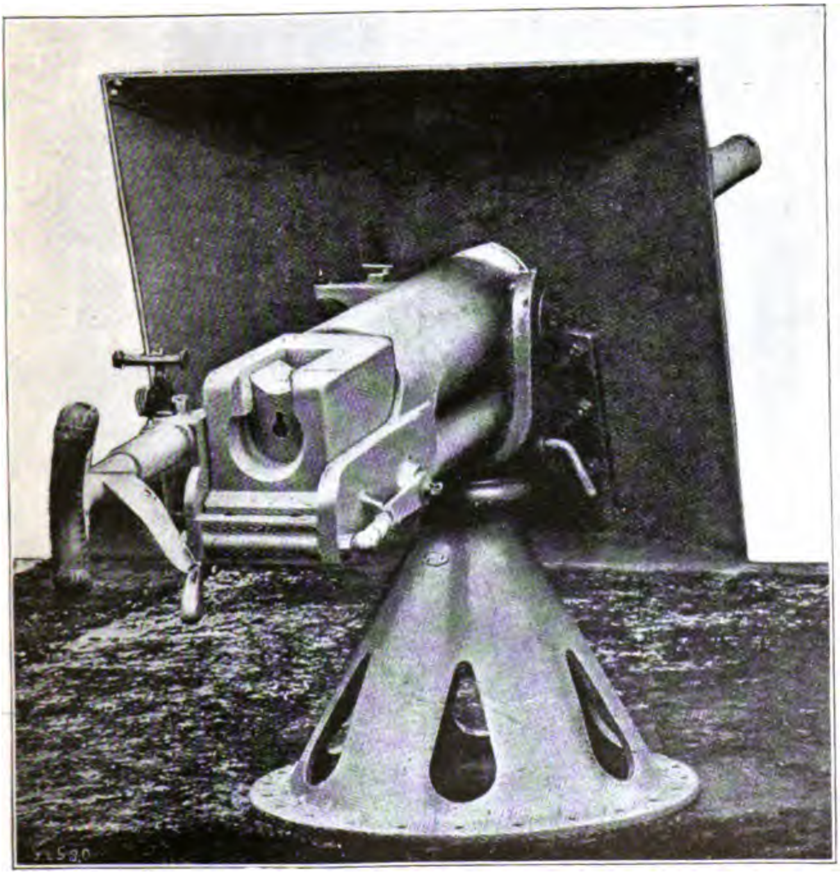


Fig. 7.—VICKERS' 14-POUNDER SEMI-AUTOMATIC NAVAL GUN.

Perforation of steel plate at muzzle by Gavre formula.	7.9 inches.
Rounds per minute	26.
Weight of mounting, complete, with shield	18 cwt. 21 pounds.
Weight of shield	2 cwt. 1 quarter 9 pounds.
Angle of elevation	20 degrees.
Angle of depression	15 degrees.

The weapon does not differ materially from the 12-pounder used by the British naval brigades in South Africa, but it is larger, more powerful, and has a greater rate of fire, due to the semi-automatic action in loading, firing, and ejecting the cartridge case. The caliber is 8 inches, and it has a total length of 161.95 inches. During recent trials the gun developed an initial velocity of 2,650 foot-seconds and a muzzle energy of 681 foot-tons, with a maximum chamber pressure of 16.5 tons. This energy, according to Gavre's formula, is equal to perforating a plate of 10.2 inches of wrought iron, or 7.9 inches of steel. A longitudinal section of the gun is shown in figure 3, and consists of a tube reinforced by a jacket and hoop. The gun is without trunnions, and is fitted into a gun-metal cradle; this is fitted with trunnions which rest in the Y's of the mounting. Two combined hydraulic and spring buffers are attached underneath the cradle, and the piston rods for these buffers are connected with the rear part of the gun.

The special feature of the weapon, the firing and breech mechanism, is shown in figs. 4, 5, and 6. Attached to the rear of the cradle is a pistol grip, containing the trigger, and on the right-hand side (figs. 1, 2, and 6) there is a lever by the movement of which the breechblock is raised or lowered. Between the buffers underneath the cradle is a powerful flat spring (fig. 4) which works the breech mechanism. To prepare the gun for firing its first round, the breech is opened by the hand lever, and by this movement a crank is turned, as shown in figs. 4 and 5. This action brings down the breechblock and compresses the flat spring between the buffers. At the same time the pivot on the crank arm presses down the cocking lever, thus pulling the firing-pin to the rear and compressing the main spring. These parts are kept in motion by the action of the sear. The breechblock, in coming down, strikes the lower extension of the extractor and causes the upper portion of it to move out from the face of the end of the barrel and brings two small projections (shown by the dotted lines in fig. 5) over the upper edge of the breechblock, thus preventing it from rising by the action of the spring. In this state the gun is ready for acting automatically. The operator has but to slide the cartridge smartly into the bore. As it enters the powder chamber its rim strikes the extractor and forces back the projections which prevented the breechblock from rising. This is practically the only hand movement in the device. The flat spring already mentioned then acts and rotates the crank which raises the block until the breech is closed. The tail end of the sear is now engaged with the toe of the trigger (fig. 4), and by drawing th pull to the rear the sear is released and the firing pin is thrown by the main spring. Upon firing, the gun recoils in the cra the combined hydraulic and spring buffers return it to batter As the gun returns, it acts upon the breech mechanism so as t the crank and thereby bring down the breechblock. The extr actuated by the fall of the latter; it first loosens the cartridge a slow movement, which, rapidly increasing, ejects it to the re

The gun is now ready for another round. The cartridge is en when the breech closes and is secured automatically. To fire, p trigger when ready. Twenty-six unaimed rounds per minute m fired. The pointing and sighting is done by the man laying the who stands with his shoulder against the shoulder piece and his hand on the pistol grip.

NAVAL LANDING GUNS.

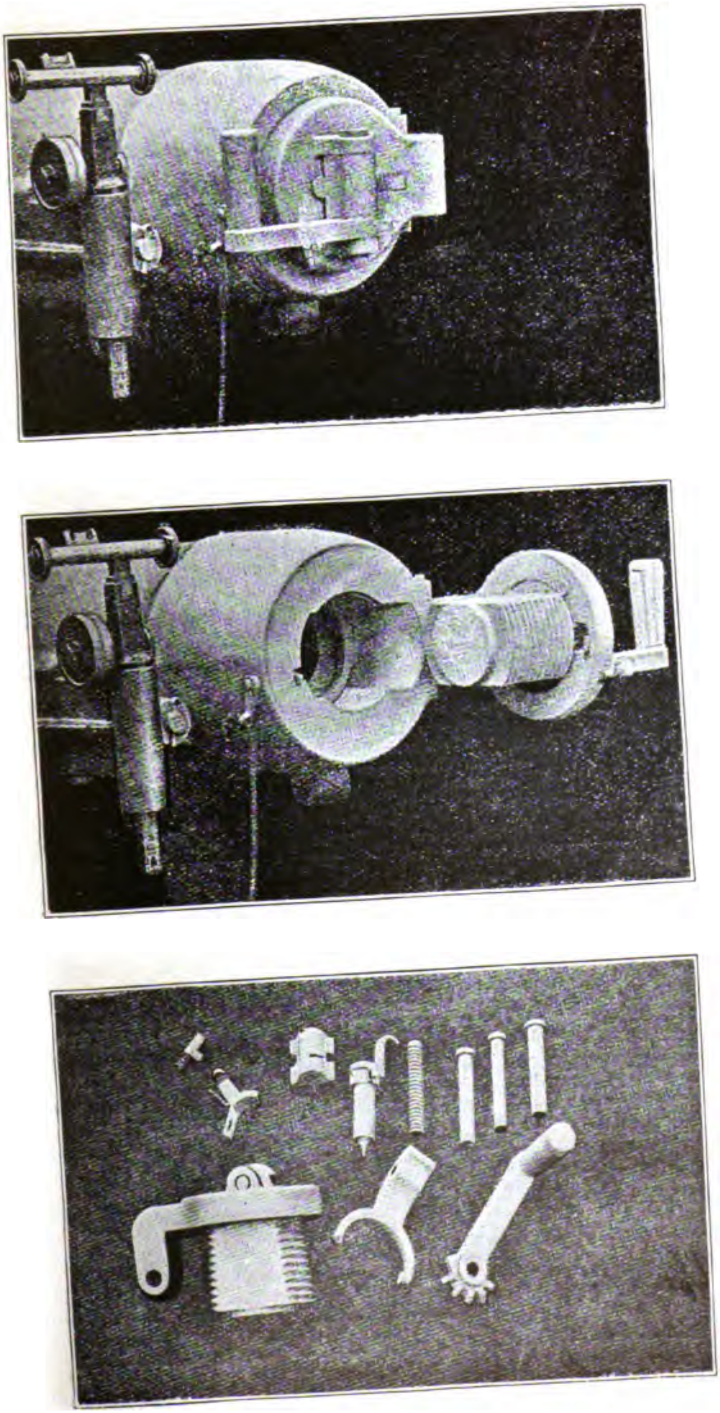
The following is a brief description of the 75-millimeter (2.95-i Vickers-Maxim quick-firer, mounted and equipped as a landing for the English navy.

Of the gun itself little need be said. It is made entirely of st and at the breech end are three lugs, one for the breech mechani and the other two for taking the piston rods of the hydraulic buffe It is constructed for firing fixed ammunition.

The breech mechanism is illustrated by figs. 1 to 7, the latt showing the principal parts as follows:

The threaded breechblock, with carrier attached to it, the first item on the lower row; the operating hand lever, the third on the lower row; the firing-pin, the fourth on the upper row; the main spring, fifth; the guide plate, third; the extractor, in the center of the lower row; the locking bolt, at the top left corner; and the trigger sear next to it, with three axis pins to the right of the upper row.

The advantages claimed for the mechanism are that a single movement of the hand lever opens or closes the breech; it can be taken apart and assembled without the aid of tools; the firing pin and spring can be changed by withdrawing the hand-lever axis only (the breech remaining closed) and, in case of a missfire, the firing-pin can be recocked by means of the hook, *a*, shown in fig. 2. Contrary to the usual practice, the breechblock is tapered or curved, as shown in figs. 2 and 3, and its largest diameter nearest the chamber when in firing position, thus increasing the safety of the breech. The block is carried on a vertical hinge or carrier, pivoted in the side of the breech, and is inserted or withdrawn from the breech by one simple movement round a hinge. Consequently, it has no longitudinal movement in the carrier. To give a clear swing to the block the opposite sides of the breech are cut away, as shown in figs. 3 and 6. The block is firmly



Figs. 5, 6, 7.—NAVAL LANDING GUN.

Fig. 8

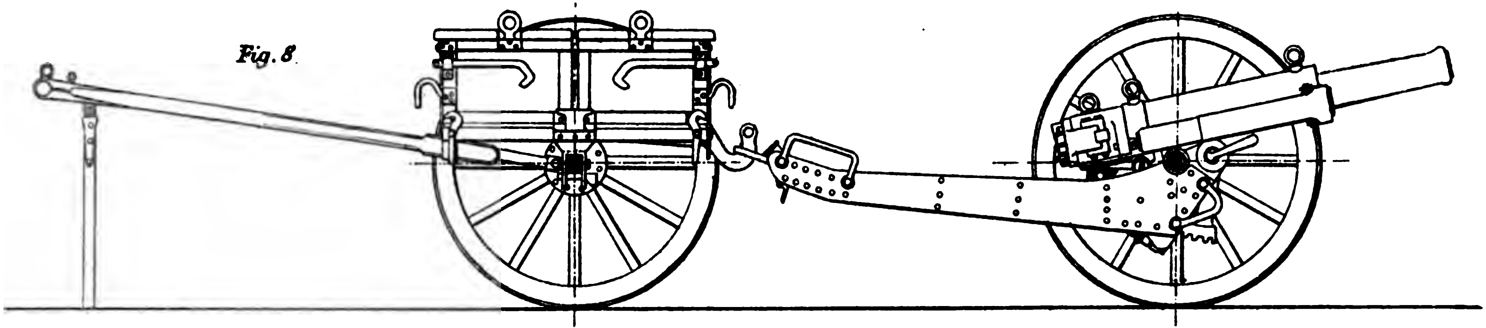
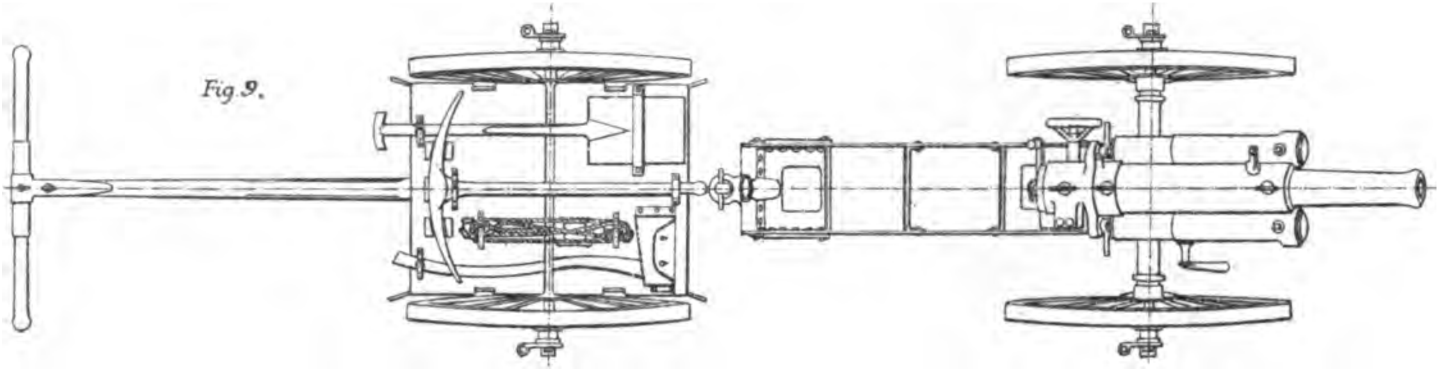


Fig. 9.



75-MILLIMETRE GUN WITH NAVAL LANDING CARRIAGE AND LIMBER.

THE NORRIS PETERS CO. PHOTO-LITHO. WASHINGTON, D. C.

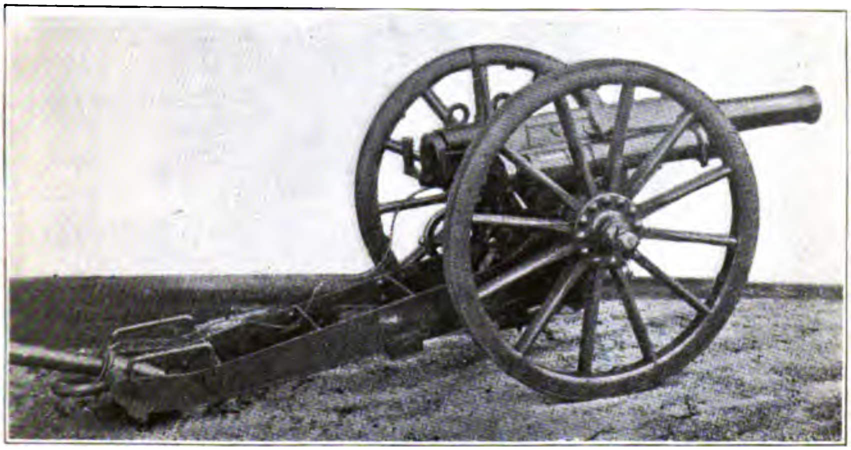


Fig. 10.—NAVAL LANDING GUN.

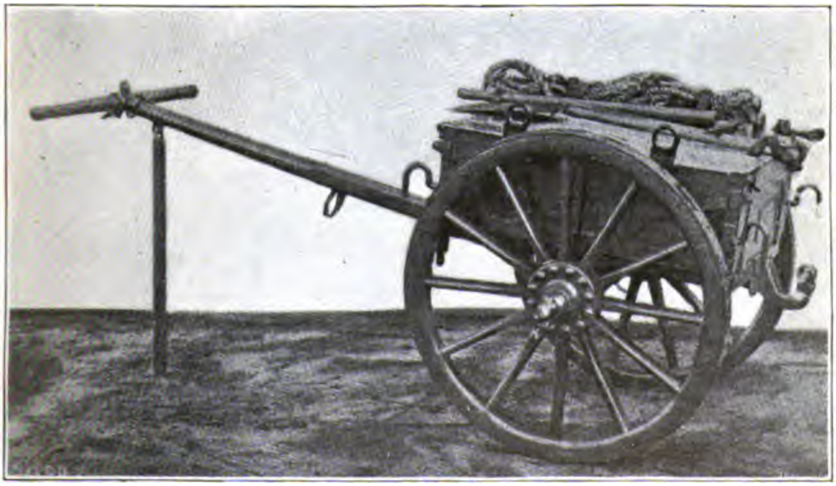


Fig. 11.—NAVAL LIMBER.

held in the carrier by continuous threads on its rear, which fit into corresponding threads in the carrier (figs. 2 and 3). A bevel-toothed segment, fitted to the rear of the block, turns it about on its axis as the hand lever is drawn to the rear. The firing-pin is actuated by the spring shown in fig. 2. The cocking of the firing-pin is effected by cams as the block turns about its axis while opening the breech. A safety attachment prevents the pin being moved while closing the breech and until the block is fully home. The extractor is pivoted forward of the carrier hinge, and its action shown in figs. 2 and 3.

The principal elements of the landing carriage and limber, shown in figs. 8, 9, 10, and 11 are as follows:

Weight of projectile	12.5 pounds.
Diameter of bore	75 millimeters (2.953 inches).
Length of bore	31.6 inches.
Length of gun, total	35.85 inches.
Weight of charge	5 ounces 100 grains.
Weight of gun and mechanism	236 pounds.
Muzzle velocity	920 foot-seconds.
Rounds per minute	12.
Length of recoil in cradle	14 inches.
Weight of carriage	602 pounds.
Diameter of wheels	36 inches.
Width of track	32 inches.
Angle of elevation	27 degrees.
Angle of depression	10 degrees.
Height of axle above ground	26 inches.
Weight of limber, including 42 rounds	1,377 pounds.

The limber consists of the following parts: The frame, ammunition chests, axles, and wheels. The frame, made of steel angles, is connected to the axle by clips and cotters, and is fitted with hooks and brackets for securing the chests. In front there is a bracket for supporting the pole, and at the rear a limber hook for attaching the trail end of the carriage. The ammunition boxes, two in number, are constructed of brass tubes held together by a steel frame. These tubes are internally of the same shape as the chamber of the gun. This prevents the cartridges being shaken during transport. Each box holds 21 rounds. The tops of the boxes are of wood covered with canvas, fitted with loops, staples, and straps for securing intrenching tools, etc., as shown in figs. 9 and 11. The limber is fitted with a pole having a crossbar for man draught and a prop. The wheels on the carriage and limber are of the same size, and are therefore interchangeable.

The other features of the gun and carriage appear to be so well illustrated that a more detailed description is unnecessary.

Another gun for landing purposes, having a total length of 51.1 inches, and firing the same projectiles, is also built for this carriage. With this latter weapon a muzzle velocity of 980 foot-seconds is obtained with a charge of 5½ ounces.

CAPTAIN SCOTT'S IMPROVISED CARRIAGES.

The necessity of a heavier field gun than the 15-pounders of the Royal Artillery became apparent early in the South African campaign. Captain Scott, of the Royal Navy, accordingly devised a field carriage for the 4.7-inch navy gun. These guns and carriages were landed with the naval brigade in South Africa and played an important part in the campaign against the Boers.

The mounting for each of the 4.7-inch guns consisted of four pieces of timber 14 feet long by 12 inches, arranged as shown in fig. 1. Over the center of this was placed the ordinary ship pedestal mounting with a spindle. The latter was then bolted through to a plate underneath (fig. 2). Thus the pedestal and timbers were securely bolted together. Next, the carriage was dropped over the spindle (fig. 3) and screwed down by its clip plate. Finally the gun, without shield, was mounted.

The following instructions were then given for mounting the gun in the field:

1. Dig a hole 14 feet square and 2 feet deep.
2. Drop the platform into it.
3. Ship the carriage and mount the gun.
4. Fill in around timbers with earth.

Subsequent experiments proved that it was not necessary to dig a hole. The platform was put down on a hard road and, upon firing, only a slight jump and recoil of the whole structure occurred. This was found to be an advantage, as it relieved the strain.

Captain Scott eventually produced a more mobile form of mount for the 4.7-inch gun. It consisted of a double trail, to admit of high-angled fire, attached to an iron axle and wheels. The latter (fig. 4) consisted of iron plates, with bushings for the axletrees in the center. Around the perimeter of the plates angle irons were bolted on each side, and on the outside were shrunk iron tires. A few strengthening strips were then put on the plates. The double trail was secured to the axletree (fig. 5) and the carriage bolted to it.

The 4.7-inch guns with General Buller in Natal are fitted with telescopic sights, also designed by Captain Scott.

A more complete idea of the construction of the mounts described can be obtained by an examination of the illustrations.

The main features of Captain Scott's latest pattern of carriage for a 4.7-inch gun are as follows:

The trail is constructed of iron instead of wood. It requires no limber to support it. A single wheel, which can be easily unshipped, is placed between the double trail. This carriage admits of 24 degrees of elevation, and with the wheel unshipped a greater angle is obtained. The mounting weighs 1 ton and 17 cwt. Twenty men can pull it about.

Fig. 1

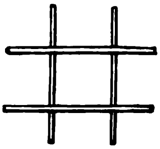


Fig 2

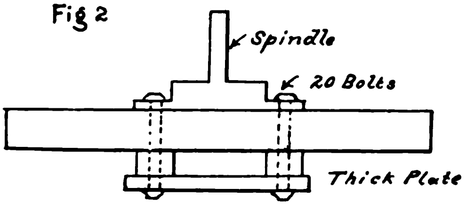


Fig. 3

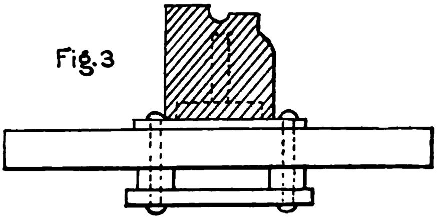


Fig. 4

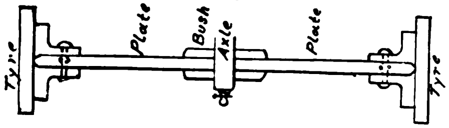
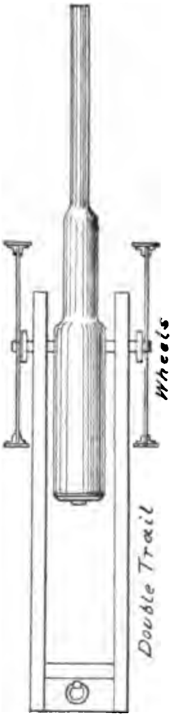
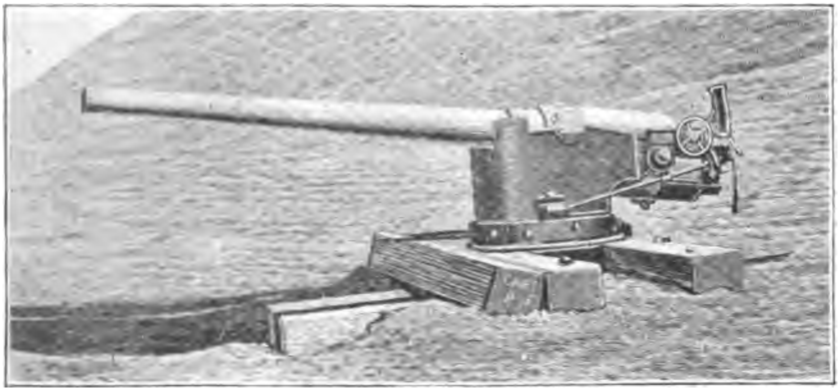


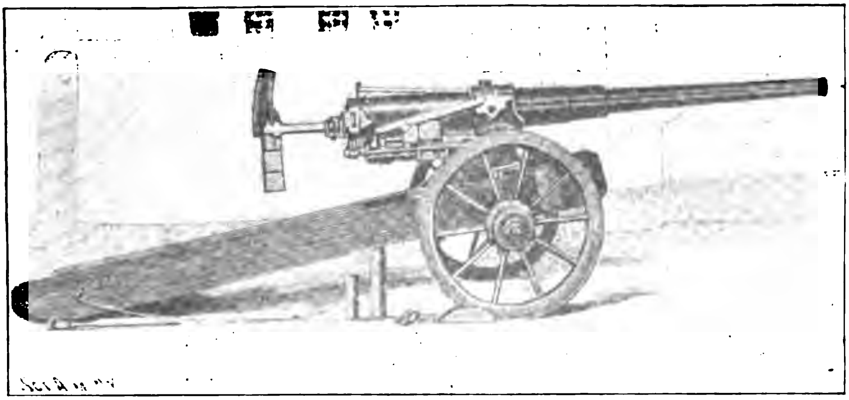
Fig. 5



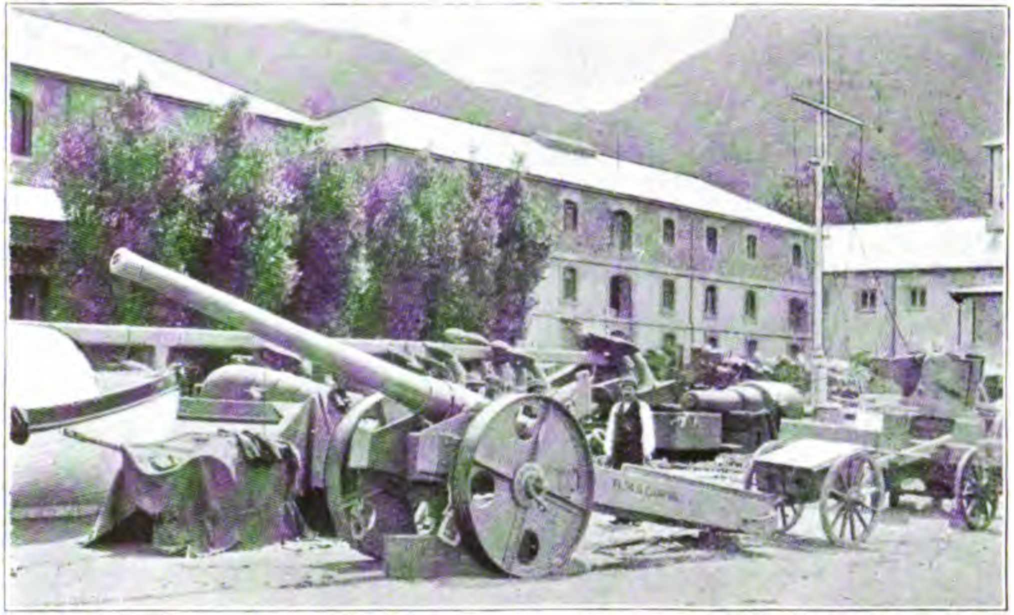
Captain Scott's Improvised Carriage.



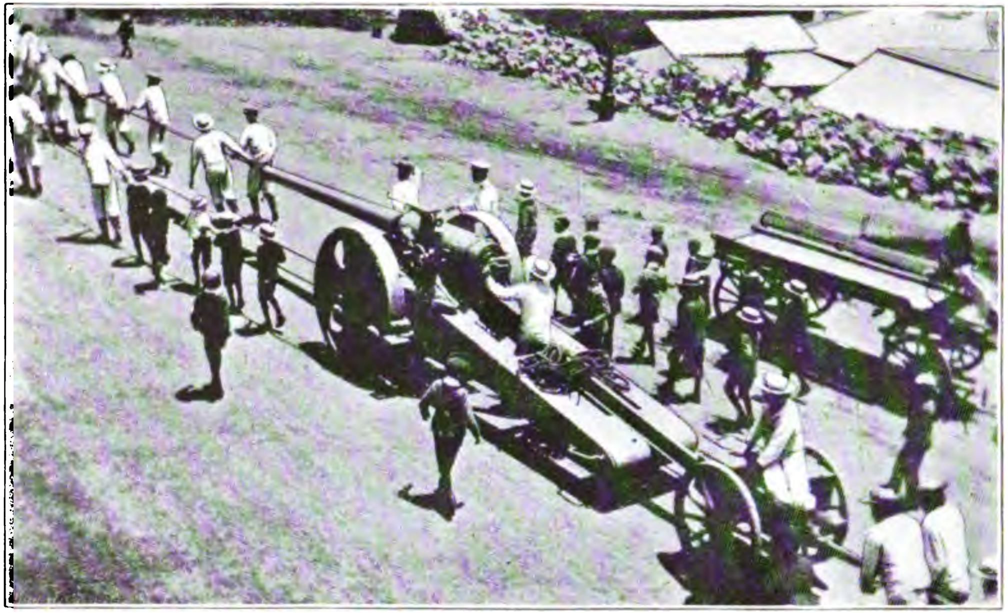
A 4.7-INCH GUN ON TIMBER PLATFORM.



NAVAL 12-POUNDER ON IMPROVISED CARRIAGE.



A 4.7-INCH GUN FROM THE FLAGSHIP DORIS.



A 4.7-INCH GUN EN ROUTE TO THE FRONT.

The principal elements of the 4.7-inch gun and its mount are as follows:

Caliber	4.724 inches.
Weight of gun	2.05 tons.
Length of gun	16.2 feet.
Length of bore, calibers	40
Number of grooves	22
Powder charge	12 pounds.
Weight of projectile	45 pounds.
Muzzle velocity	1,786 foot-seconds.
Muzzle energy	995 foot-tons.
Muzzle perforation, iron	8.5 inches.
Gun sighted to	8,000 yards.
Weight of cradle	15.5 cwt.
Weight of carriage	27 cwt.
Weight of shield	21.5 cwt.
Weight of breastplate and rollers	2 tons.
Total weight of gun and mount on board ship	7.25 tons.

The guns now in use in South Africa on Captain Scott's mountings are as follows: One 6-inch wire gun on a traveling carriage; seven 4.7-inch guns on traveling carriages; one 4.7-inch gun on railway truck; five 4.7-inch guns on platform mountings; twenty-four 12-pounder 12-cwt. guns on traveling mountings; making a total of 38 heavy guns.

NAVAL PEDESTAL (SPRING-RETURN) MOUNT FOR 15-CENTIMETER (5.91-INCH) R. F. KRUPP GUN.

Krupp's naval guns of this caliber are mounted in two ways, in barbette (gravity-return) and in pedestal (spring-return) carriages. Fig. 1 represents a 15-centimeter (5.91-inch) gun in a central pivot barbette carriage, which is shown only that its construction may be compared with that of the pedestal mount. Both systems can be used for rapid-fire guns of any caliber. The essential difference between them consists in the manner in which the gun recoils and is returned to battery. In the gravity-return carriage (fig. 1) the gun, together with the top carriage upon which it rests, slides back upon the inclined slides of the lower carriage, the recoil being checked, in about 2½ calibers, by a hydraulic piston. The gun returns to the firing position by its own weight. The force of the recoil is absorbed by the recoil cylinders and also in driving the gun up the inclined slides. The lower carriage rests upon ball-bearings in the bed-plate which is bolted to the deck. These bearings are the most delicate part of the carriage, the most liable to injury during gun practice, and, at the same time, the part most difficult of access. That the gun should work properly they should at all times be kept scrupulously clean. In this mount the gun recoils, as we have seen, in a line parallel to its primitive axis, whilst in the pedestal mount it follows the line of the axis itself.

In consequence of this the opening in the shield of the last-mentioned mount need be no larger than is necessary to permit the maximum elevation of the gun, while in the other the opening must be high enough to permit the ascending recoil. The protection afforded the crew is much less complete, and this is especially so when the gun is mounted to admit of high elevations and the shield is in the form of a hood. In this case the opening in the roof of the shield must be made deeper. In the pedestal mount the shield is brought much nearer the trunnions and the area of the openings can thus be greatly reduced.

In the pedestal type of carriage (fig. 2) the gun rests in a sleeve or jacket of bronze or steel, which is provided with trunnion bearings; this surrounds the gun to which it acts as a slide during the recoil. Guides prevent the gun turning about in its longitudinal axis in a direction opposite to that of the rifling. The recoil is checked by hydraulic cylinders and by return springs located in casings at both sides of the recoil cylinders. The coil springs in these casings are compressed during recoil and automatically return the gun to battery. The cylinders of the recoil brake and of the recoil-return springs are generally attached to the cradle and hence do not participate in the recoil of the gun. Their piston rods, however, are attached to a hoop or lug on the gun. In place of the springs a hydro-pneumatic brake may be employed with especial advantage in guns of large caliber. Various positions are assigned to the recoil brakes and to the recoil-return springs of the pedestal mounts. When placed beneath the barrel (figs. 2 and 3) they are less exposed to shot or shell. The sights in the pedestal mount, being fixed to the cradle, do not recoil with the gun.

In the pedestal mount (figs. 2–7) the cradle rests in two arms of a fork (figs. 6 and 7). The yoke A, with its hollow pivot, turns in bearings bushed with bronze. The weight is borne chiefly by the auxiliary pivot, which has slight lateral play and which plays upon an arched step bearing, *f*. The pivot yoke is supported by ball bearings, the distance between the pivot and the step bearing being so regulated by the thread *g* that the auxiliary pivot alone carries the yoke and gun. In training the piece only the slight friction of the ball bearings has to be overcome. The screw *g* can be entirely removed, without dismounting the gun, in order to repair or clean the ball bearings. The small size of the stand compared with that of the gravity-return carriage effects a great saving in space and weight. The gun can be elevated to 30 degrees. That this may be done the pivot yoke is cut away at *h*. The arrangement of the trunnion boxes differs in construction from those in general use. They open toward the rear instead of the top, and are closed by a block, *d* (fig. 6), which is inserted laterally. This block is held in place by the plates *b* and *c*. Among the advan-

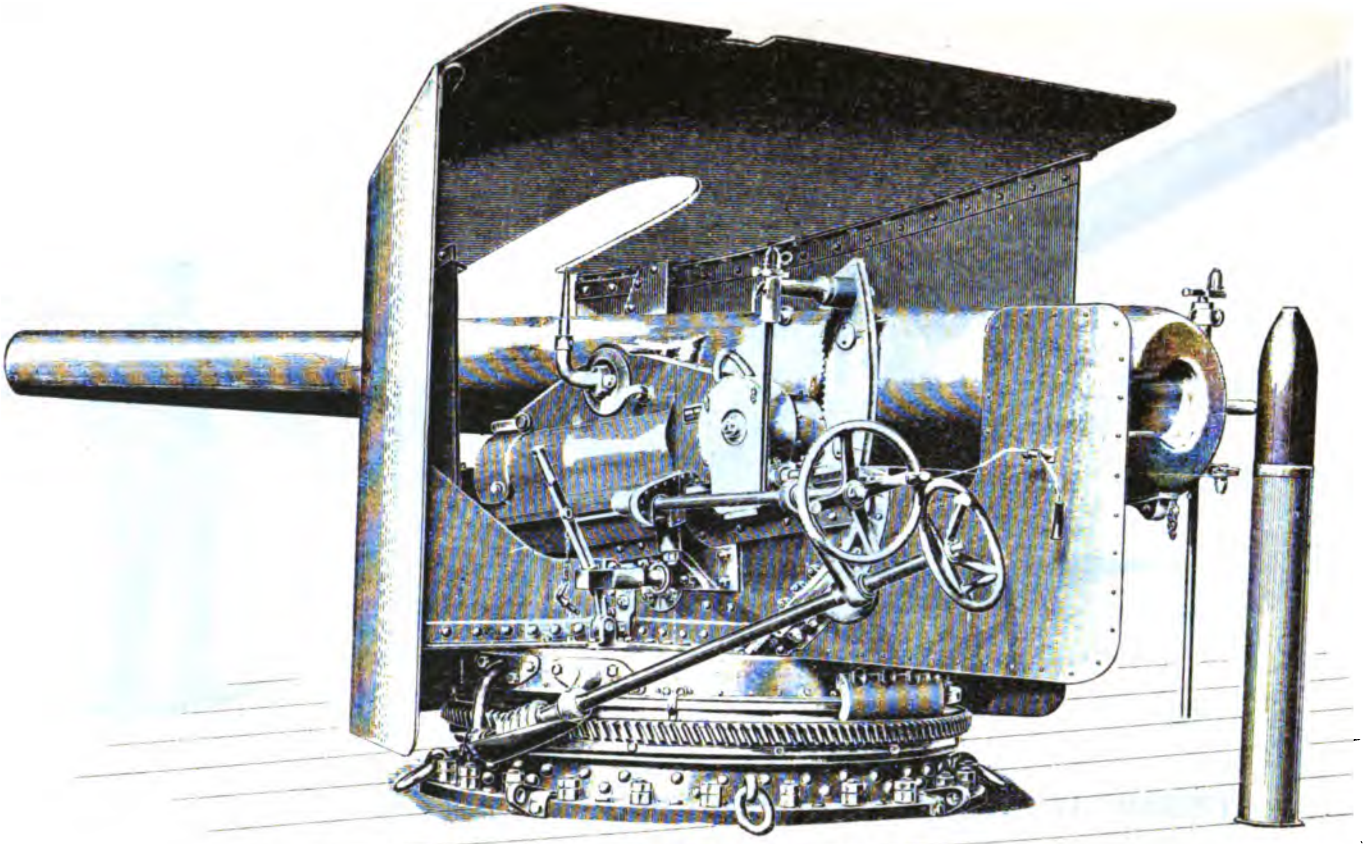


FIG. 1.—KRUPP 15-CM. (5.91-INCH) GUN, BARBETTE MOUNT.

THE NORRIS PETERS CO. PHOTO-LITHO. WASHINGTON, D. C.

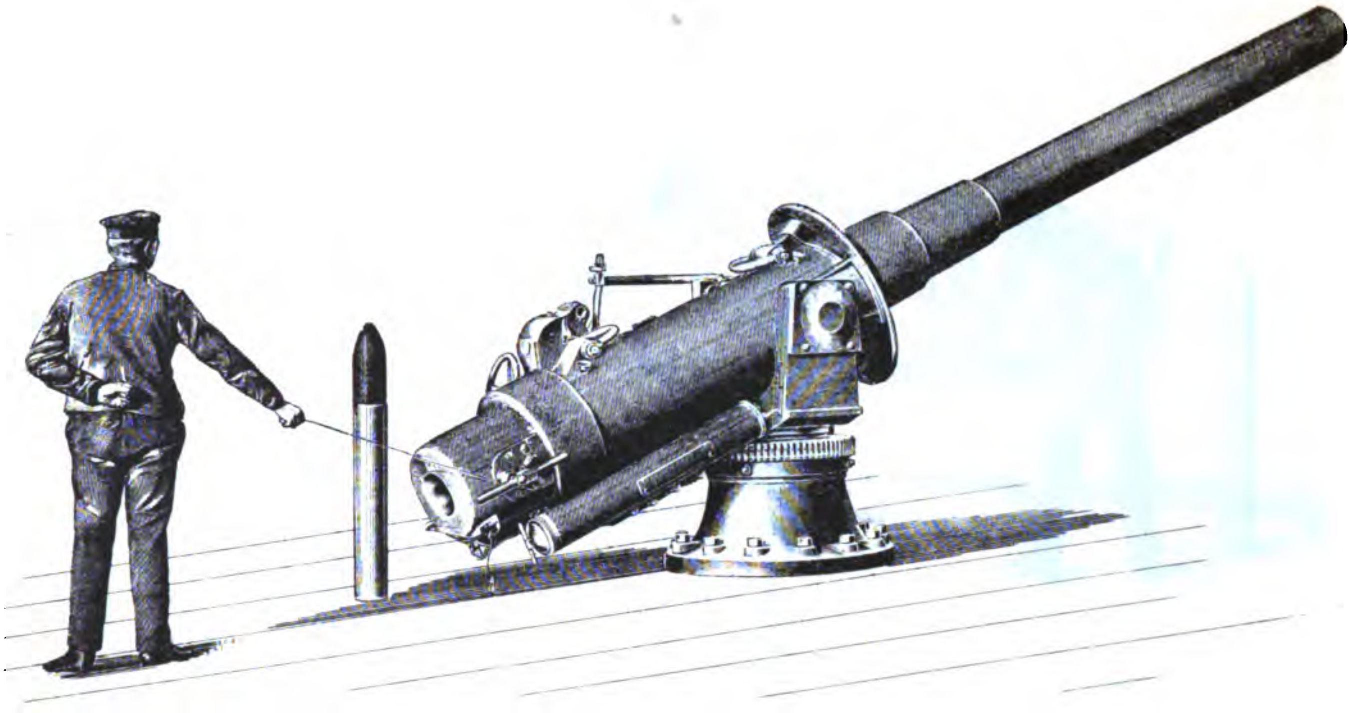


FIG. 2.—KRUPP 15-CM. (5.91-INCH) GUN, PEDESTAL MOUNT.

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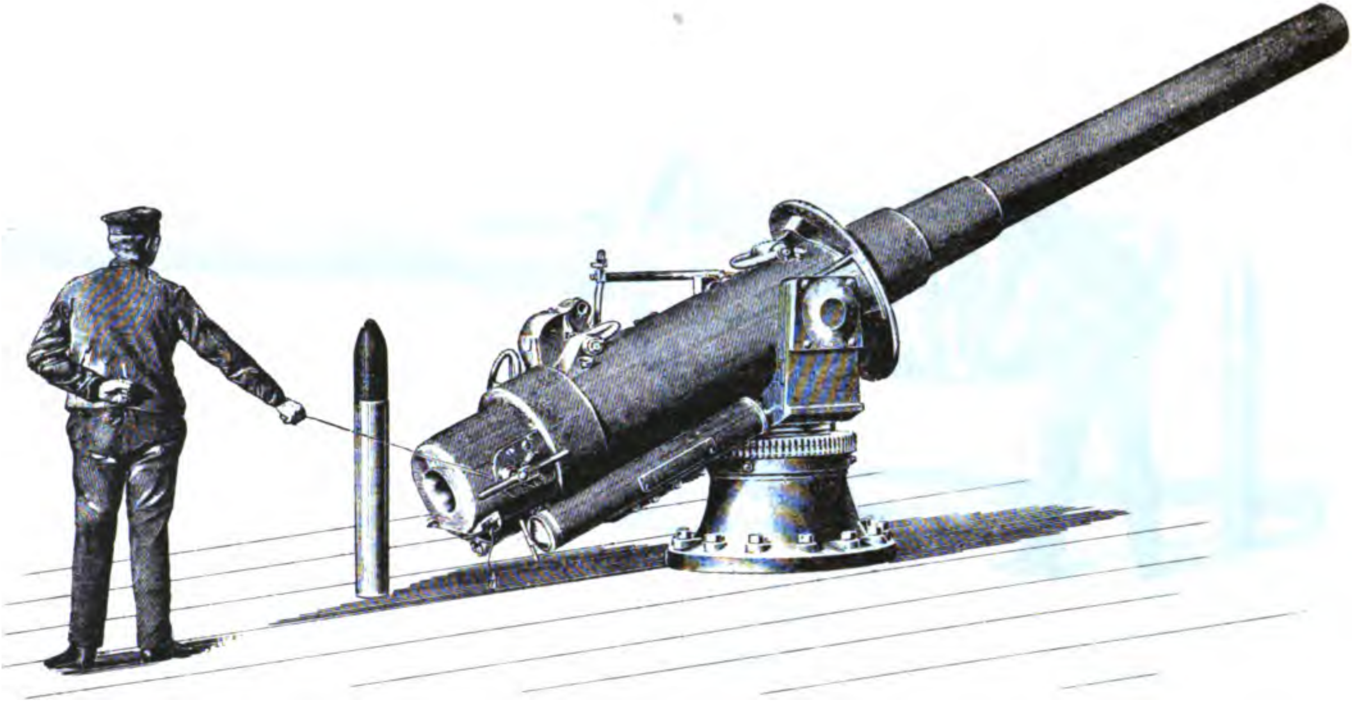

FIG. 2.—KRUPP 15-CM. (5.91-INCH) GUN, PEDESTAL MOUNT.

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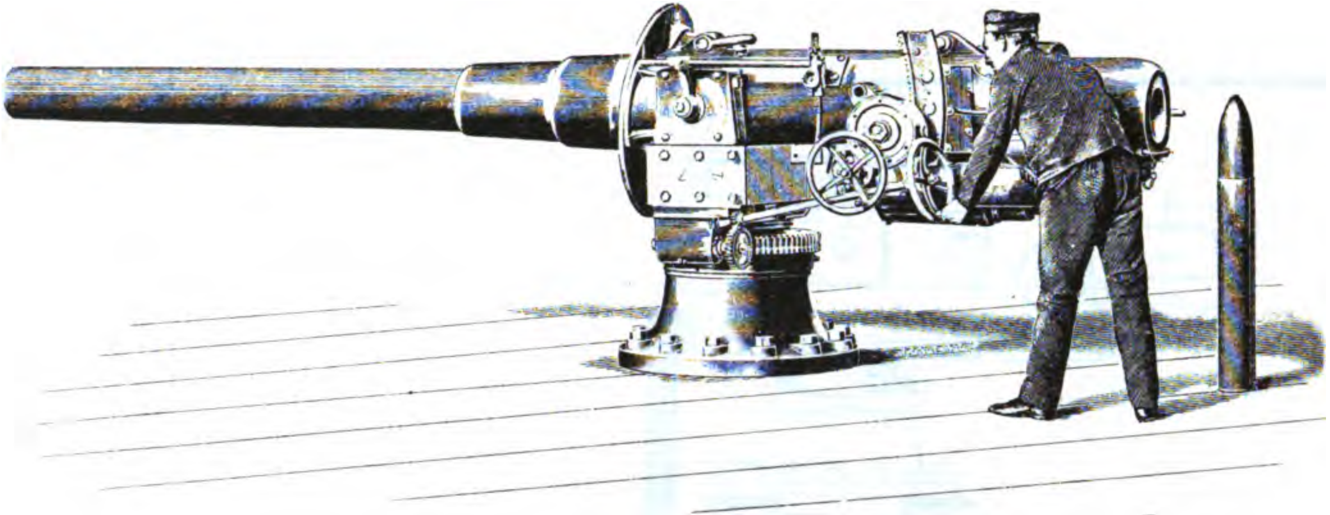

FIG. 3.—KRUPP 15-CM. (5.91-INCH) GUN, PEDESTAL MOUNT.

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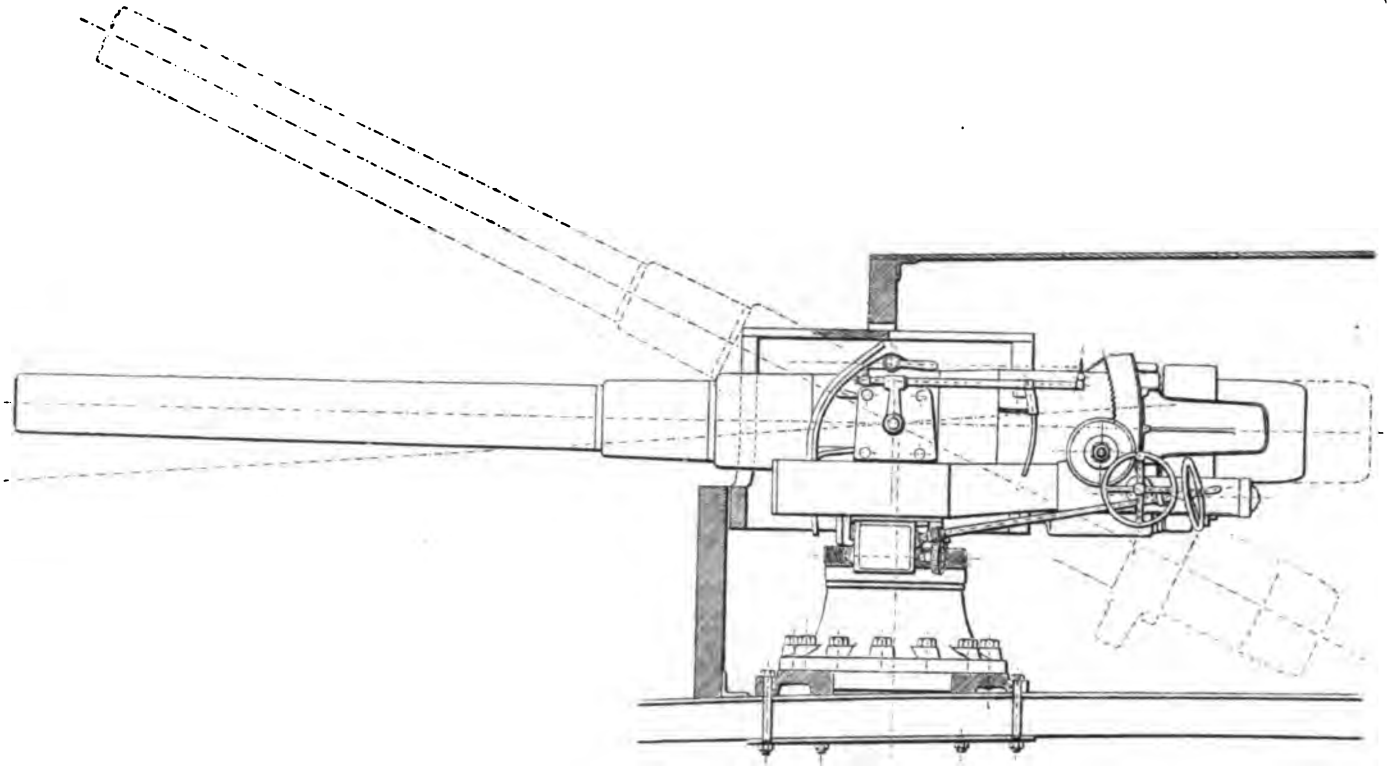

FIG. 4.—KRUPP 15-CM. (5.91-INCH) GUN, PEDESTAL MOUNT.

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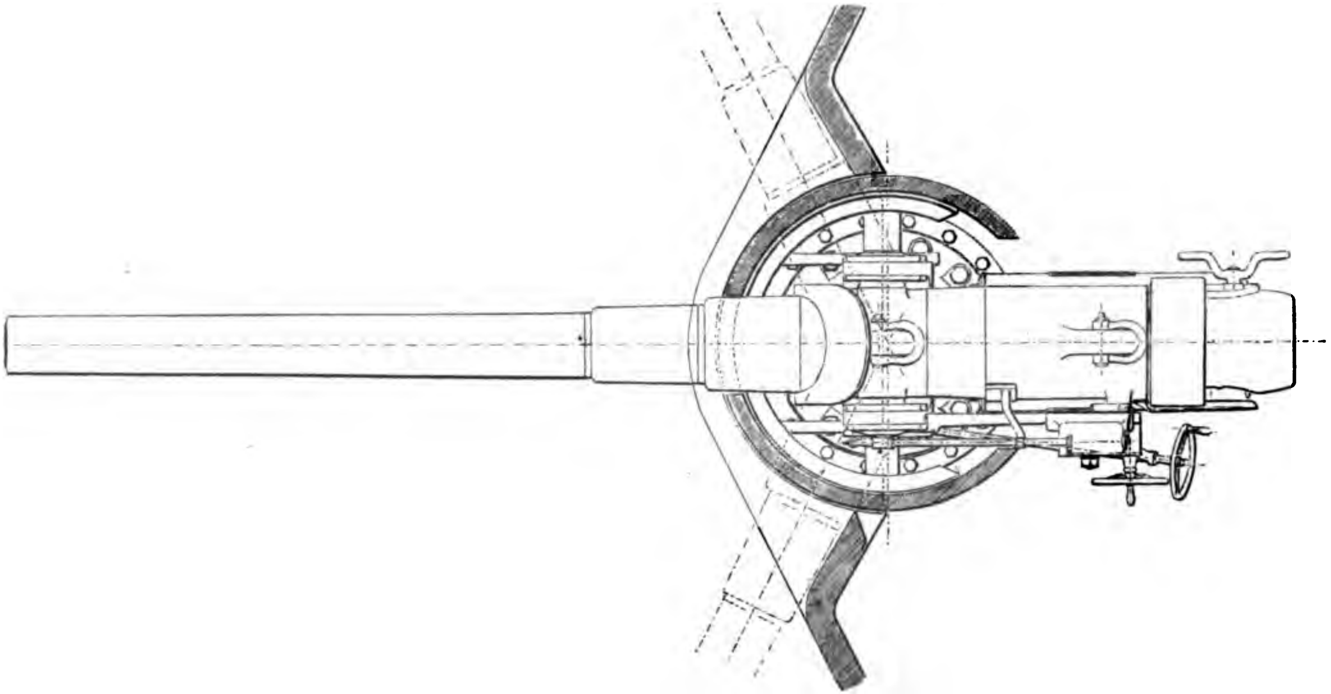


FIG. 5.—KRUPP 15-CM. (5.91-INCH) GUN, PEDESTAL MOUNT.

E NORRIS PETERS CO. PHOTO-LITHO WASHINGTON, D. C

tages claimed for this carriage is the readiness with which the gun can be dismounted. To do this the exterior plates are taken off by removing the bolts; the interior ones are withdrawn and the blocks *d* removed. Since the height of the latter is equal to the diameter of the trunnions, the gun and cradle can be removed from the carriage (without raising the gun) by means of a truck carriage to which the shackles on the sleeve have been attached.

On the left side of the forked pivot (fig. 7) is bolted the flat arm *i*, to which the training and elevating gears are attached. The latter are well shown in fig. 3.

Different forms of shields are employed with this mount. That the gun's crew may be equally well protected in all positions of train, the shield should turn with the gun, and it must therefore be connected with the forked pivot. This may be done equally well whether the supports of the shield are angular or curved. By preference they are attached to the vertical arms of the fork. The small diameter of the pedestal permits the shield to be brought very close to the trunnions, and the opening is thus greatly reduced. The slight space remaining between the gun and the shield may be completely closed by a collar attached to the forward extremity of the cradle.

The 15-centimeter (5.91-inch) guns installed in the *Kaiser Friedrich III*, which are not placed in turrets, are on the spring-return pedestal mounts just described.

THE 7.5-INCH QUICK-FIRING VICKERS-MAXIM GUN.

A glance at the latest battleship designs is sufficient to show the great increase in the area protected from harm by rapid-fire guns. A little closer examination will reveal the fact that 6-inch guns, the largest quick firers in general use, are to be protected by as many inches of plate. This protection has created a demand for a heavier weapon—that is, one which can be fired rapidly and can successfully attack armor of the above-mentioned thickness. Accordingly, the English have produced a 7.5-inch gun, firing a 200-pound projectile, that can be fired six times a minute.

The principal elements of this weapon and its mount are as follows:

Diameter of bore	7.5 inches.
Length	375 inches = 50 calibers.
Total length of gun	386.7 inches.
Diameter of chamber	11 inches.
Length of chamber	54.25 inches.
Maximum pressure	17 tons.
Muzzle energy	11,825 foot-tons.
Nature of charge	Cordite.
Weight of charge	50 pounds.
Weight of projectile	200 pounds.
Weight of gun and mechanism	16 tons 1 cwt.

Weight of mounting with shield	10 tons 14 cwt. 2 quarters.
Thickness of shield	3 inches.
Weight of shield	2 tons 1 cwt.
Angle of elevation	16 degrees.
Angle of depression	10 degrees.
Rounds per minute	6.

The gun is built up on the wire-wound system. From the above table it is seen that it develops a muzzle energy of 11,825 foot-tons, or 730 per ton of gun, in conjunction with a rate of fire of six rounds per minute.

The breech mechanism is of the standard Vickers type. The block is divided circumferentially into segmental portions in regular steps of varying radii. There are eight segments, and of these six are threaded, so that three-fourths (instead of one-half) of the circumference does work in resisting the pressure. This enables the block to be shortened by about one-third its length. The weight thus saved is added to the muzzle.

The mounting illustrated consists of a top carriage resting on a horizontal roller bearing upon a steel pivot. The gun recoils in a cylindrical cradle to which are attached three cylinders, one to overcome the recoil and the other to contain the springs which return the weapon to battery. The connection between these cylinders and the gun is made by arms projecting from the breech ring. The elevating and training are done by two handwheels placed near the shoulder piece against which the gun pointer leans. The loading gear is an interesting feature. It consists of a shot tray pivoted on the side of the cradle, so as to move with the gun when the latter is elevated, depressed, or trained. The tray is swung into position by hand. Fig. 1 shows the tray in position behind the breech, with the projectile resting in it.

TURRETS AND TURRET MOUNTS.

ELECTRICALLY CONTROLLED TURRETS.

SCHNEIDER-CANET.

The first electrically controlled turret was installed on the *Capitan Prat* by the Creusot people. Since that time the system has been so perfected and has grown so in favor that it is now generally preferred to the hydraulic.

From the moment that electricity began to be used to work the auxiliary machinery of modern vessels it was but a comparatively short time before this form of power found its place in working turrets.

The advantages claimed for the Schneider-Canet system may be summed up as follows:

1. Lateral training is insured by means of a hand lever placed within easy reach of the gunner, and which he moves in the direction he wishes to give the turret. This manœuvre is of the simplest character and can be carried out by any untrained hand.

2. The rotary speed of the turret is proportional to the extent of travel of the hand lever, and training can be effected at all speeds up to the maximum. Whatever be the rate at which the hand lever is worked, the turret always steadily revolves, and without shocks.

3. The turret when revolving at full speed in one direction can be reversed at full speed in the other direction without injuring the system.

4. The system is so sensitive that even the largest turrets can be turned through less than one-twentieth of a degree in either direction, and to effect this no special mechanism is necessary. No mistake is possible in the manipulation of the working devices, and the gun can always be exactly sighted.

5. The turret can be stopped suddenly without shock and without the weight of the moving mass exerting any local injurious strain.

6. If through mistake the gunner does not stop the turret before the extreme limit for training is reached, that is to say, before it strikes against the mechanical buffers, the system comes in contact with an electrical buffer that stops it automatically, while the connections return to zero under the action of a counteracting spiral spring.

7. The working apparatus proper placed in the turret takes up but little room, thus giving more space for the personnel; all the inside connections being prepared separately the apparatus is easily put in place, and should it get injured in any way it can easily be replaced by a spare one, the making up of the connections taking but little time.

8. All the Schneider-Canet electric turrets are so arranged that if for any reason the electric motor is not used, the various operations—the training and the elevating of the gun and the hoisting of the ammunition—can be performed by hand-worked direct-acting cranks.

The annexed plates illustrate a closed-in turret for two 12-centimeter (4.724-inch), 45-caliber, quick-firing guns of the Schneider-Canet system.

The guns are fitted with one-motion breechblocks, arranged for firing both electric and percussion primers. A jacket with shoulder extensions surrounds the gun and carries on the sides two slides that support and guide it during recoil by bearing on the top surface of the string beams. In front of the jacket are buffers, and underneath is placed the recoil cylinder, in connection with which is placed a spring recuperator. The movable cradle consists of a front and rear collar and of two lateral string beams which unite them. During recoil the gun slides in the frame thus formed; the trunnions are in front. The gun in recoiling draws with it the recoil cylinder, the piston remaining fixed. The liquid passes through an annular opening from one side of the piston to the other. The Belleville springs are compressed until the recoil is complete. They then relax and the gun returns to battery.

The movable part of the turret is balanced on its vertical axis of rotation. The platform consists of a flooring of steel plates strengthened by T-beams and by a ring made of angle bars; it carries the pivoting column, which is in the shape of a truncated cone, and the roof. The guns are elevated by hand; to this effect each of the outside string beams is fitted with a toothed sector which engages pinions keyed on the same shaft with a helicoidal wheel worked by an endless screw. On this shaft is keyed the handwheel operated by the gunner. The lateral training mechanism is worked by electricity or by hand; in the former case the motor, which is placed in the front part of the turret, drives, through an endless screw, a helicoidal wheel that operates an inside gearing with differential motion. This gearing is keyed on a vertical shaft, at the lower end of which is a pinion that gears with two other pinions placed symmetrically, and engage the toothed circular rack for lateral training. The gunner regulates the training at will. In the device for lateral training by hand power the men work two cranks placed one on each side of the mountings; these transmit power through a chain to a shaft fitted with an endless screw which gears in a helicoidal wheel that surrounds the differential gearing above referred to. The helicoidal wheel operates the vertical shaft provided with a pinion which engages the circular rack for lateral training. The two mechanisms are absolutely independent one from the other.

Ammunition is raised to the top platform by means of a hoist placed in the central tube. The hoist consists of two endless chains between which are held the buckets which contain the cartridges. During the raising motion the cartridges are guided by gun-metal slides placed on the whole height of the tube; the chains are, moreover, provided with crosspieces placed at the height of the cartridge cases. The chains in descending are also guided in a brass tube. The buckets are thus kept in position and remain always suitably placed for receiving the cartridges to be raised. The automatic feed of the hoist is insured by a device worked by the chains and on which the men deposit the cartridges. For working the device, the chains are provided with suitable catches which act on a horizontal rack that sets in motion a pinion keyed on the shaft of the hauling-in arm; the latter consists of a forked-shaped lever which receives the cartridges in such a way that the bottom of the cartridge case rests first on a small roller placed between the branches of the fork, the point of the projectile bearing against a catch at the opposite end; this catch disappears when the fork-shaped lever is raised, the cartridge reaches a vertical position, slides down and rests in the bucket which is ready to receive it. The hauling-in device holds the cartridge until the bottom of the cartridge case enters the guiding tube; it then falls back to its original position to take up a fresh charge. When it has reached the top part of the tube, the cartridge is inclined while it passes through the opening provided beween the mountings by bearing on a roller suitably placed for this purpose; it then pivots around the bucket trunnions until it slides by gravity in the trough prepared to receive it. As soon as the car-

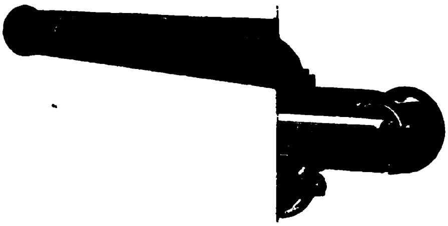


Fig. 2.

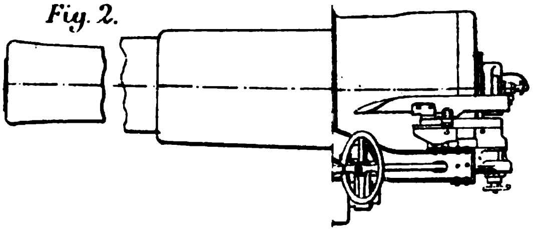
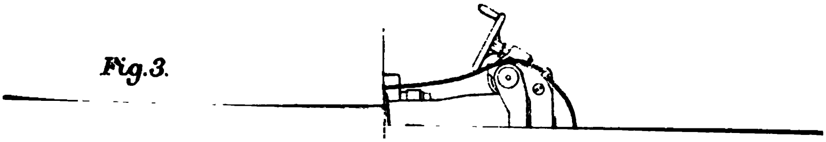
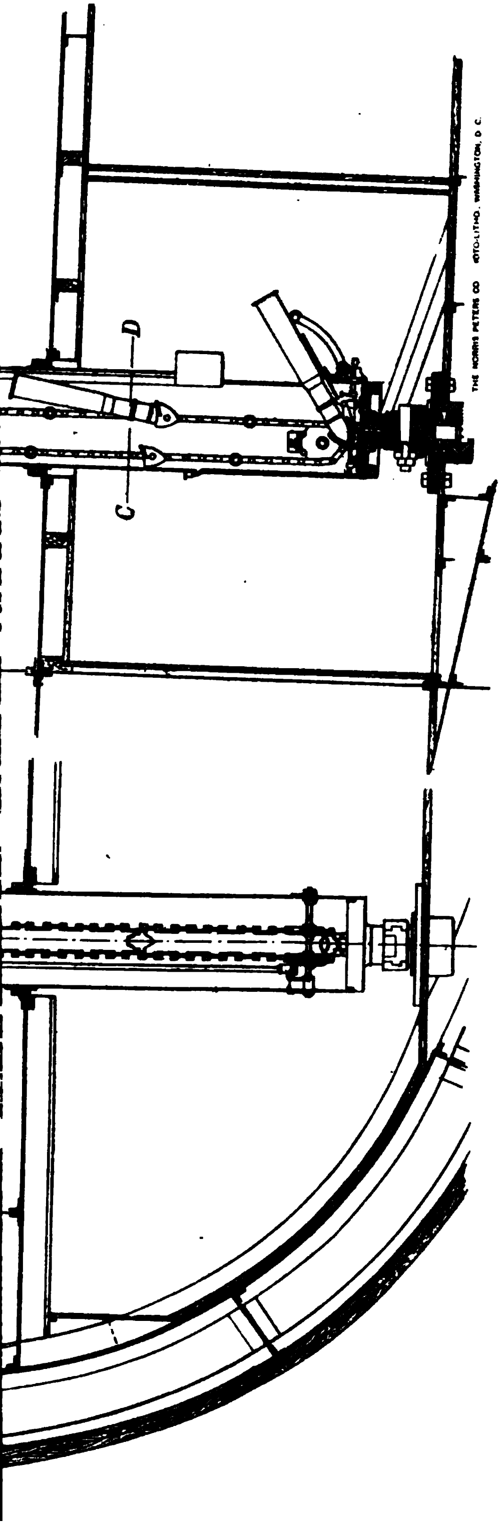


Fig. 3.



SCHNEIDER-CANET ELECTRICALLY WORKED TURRET FOR TWO 10 CENT. GUNS



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tridge has left the bucket the bottom end of the latter strikes against a fixed butt, which places it straight again, ready to follow the guide that surrounds the descending chain. The electric motor for working the hoist is joined to the central tube below the armored deck. It works a shaft through an endless screw and a helicoidal wheel that surrounds a set of differential gearing; this drives a shaft arranged to work another spindle placed at the lower end of the tube, and on which are keyed the pinions that drive the hoist. For operating the hoist by hand power it suffices to turn the central shaft by two cranks, the gearing above referred to transmitting the motion.

ARMSTRONG 12-INCH TURRET.

A sectional elevation of the Armstrong design of a 12-inch turret for H. M. S. *Formidable* and class is shown in the accompanying plate.

The central ammunition hoists are contained in a cylindrical casing 6 feet 6 inches in diameter, extending from the under side of the working chamber to within 2 feet of the ship's bottom. This casing revolves with the mounting and contains a pair of shot hoists and a pair of ammunition hoists. The bottom of the casing is fitted with rails, on which a pair of bogies, carrying shot trays, can run. These are arranged to be locked to the ship while being charged, and to the hoist casing while discharging into the shot cage. The projectiles, on reaching the working chamber, are automatically rolled out on an inclined trough leading to the gun hoists.

In describing this mount the *Engineer* says:

> A new departure in this design is the loading of the guns at an elevation of only 4½ degrees. There exists an impression that time can be saved if the guns can be loaded at any angle without coming to a fixed position. If, however, the bore has to be washed out after each round, it would have to be placed at about 4 degrees or 5 degrees of elevation, to allow the water to run out of the chamber. This, and the provision of something to catch the water, seems to make it desirable to place the gun on a stop at this position. On the comparatively rare occasions when more elevation is required the stop can be easily removed.

The rammer G is of the chain type. That the English are by no means convinced that it is more efficient than the hydraulic rammer is shown by the following comment:

> This (chain rammer) saves room in a fixed loading position by reducing the length of the oval barbette; but, as now applied to all round loading, its advantage is questionable. In the hydraulic rammer the machine is in the line with the work, and delivers a direct stroke in a straight line; there can be no advantage in converting rectilinear motion into circular. Moreover, the hydraulic rammer is made up of few pieces, and weighs only one-fourth as much as the chain rammer of similar power.

In spite of the above it appears from the following account of a recent gun-mounting trial that the Admiralty has decided to adopt a chain rammer, designed by the Elswick firm, for vessels of this class.

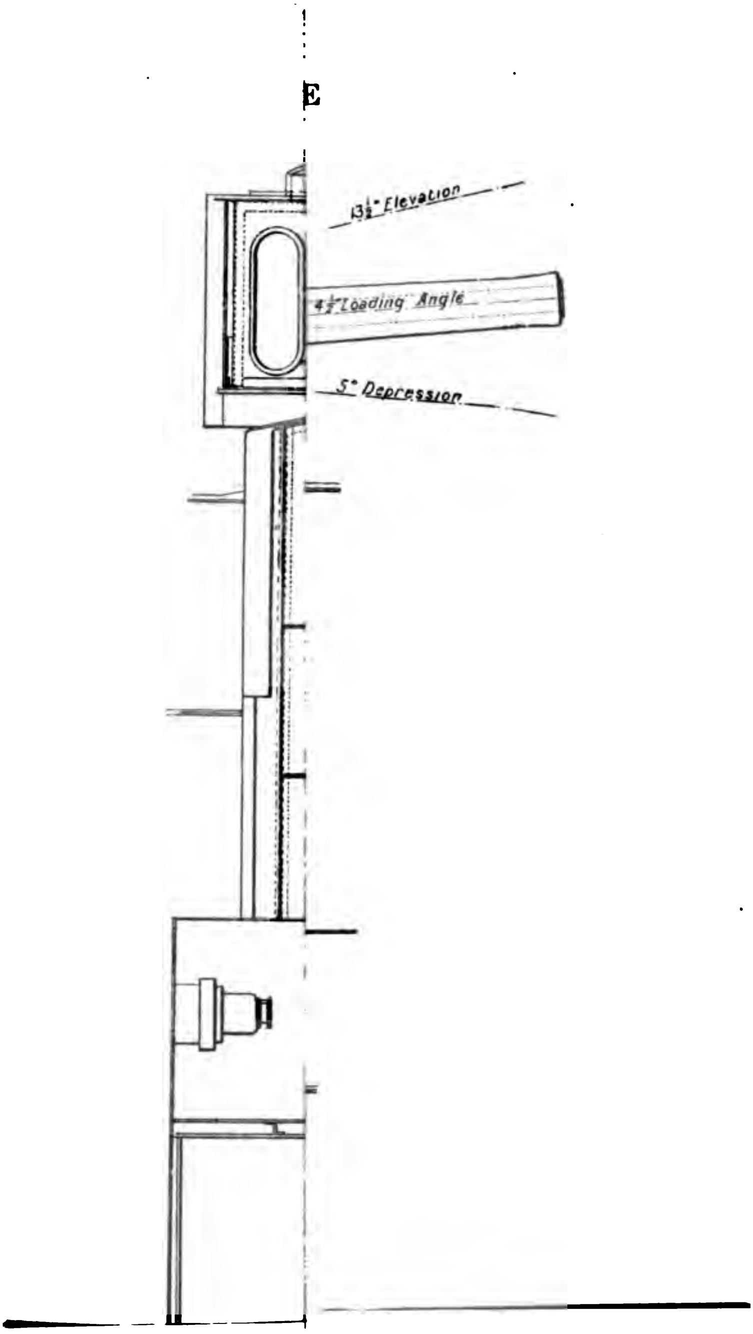
The *Drudge*, experimental gunboat, left Portsmouth for the trial of the Armstrong mounting for the 12-inch wire-wound Mark IX gun. Six rounds were fired, all at the horizontal position; the first with a half charge, then two rounds with three-quarter charges, and three rounds with full charges. The mounting stood the test admirably, but at the sixth round the concussion caused a cracking of the plates at the bows of the vessel. The *Drudge* had to return into harbor for immediate repairs.

The gun mounting is designed for the class of ship of which the *Formidable* is the type. Although similar in most respects to the gun mounting adopted for the *Albion* and *Glory*, some slight modifications have been made with the hope of still further increasing the rapidity of fire. All heavy gun mountings up to the present have been arranged for their main loading position to be with the gun at the extreme elevation (13½ degrees); thus after firing it was necessary to lower the breech of the gun, and after loading to raise the breech of the gun from this position. This double operation occupied a certain interval, and it is the object of the new design to omit this interval. The loading position is therefore fixed at 4½ degrees of elevation, this angle having been selected for two reasons. First, after firing it is the custom to wash out the breech with water in order to extinguish any hot material that might possibly have been left in the chamber after the previous round, and the chambers of the 12-inch guns are so formed that water will not run out of them at any angle less than 4½ degrees. Secondly, from 3 degrees to 4 degrees of elevation is considered to be the angle at which the gun will be most frequently used when it is required to fire it rapidly; hence to lay it at 4½ degrees would require practically no loss of time. The angle is also a convenient one for charging the gun, in that it allows the rammer to be snugly stowed away and the loading operations to be kept well in sight. It is also a convenient angle for the opening and closing of the breech screw, and the insertion and extraction of the primer.

The rammer is of the chain type. Such rammers have been for a long time proposed, but there have until recently been practical difficulties of carrying the idea into practice. The trial of a chain rammer, however, made at Woolwich and tried in the *Royal Sovereign* having proved successful, the Admiralty decided upon adopting these rammers for the *Formidable* class. Having formed this decision, they left the matter of design in the hands of the Elswick firm, with the result that a chain rammer of exceptional rapidity in working has been produced. The speed of ramming home and of withdrawing the rammers in the *Cæsar* and *Illustrious* was eight seconds, whereas the speed of similar movements in the *Formidable* class is to be reduced below six seconds. As each round involves twice ramming—once for the shot and once for the powder—a greater rapidity of the rammers will save an interval of between three and four seconds per round. It is hoped that the reduced loading angle will save a further interval of from seven to eight seconds per round. The Armstrong mountings in the *Cæsar* and *Illustrious* already enable the guns to fire at intervals of 1 minute 42 seconds.

In the *Formidable* mounting there are also improvements in the arrangement of the cage for bringing up the ammunition, which may add slightly to the rapidity and will add to the efficiency and ease of working. A complete system of hand mechanism has been fitted to the *Formidable* mounting, so that the gun may be lifted, depressed, run in, or run out without any assistance from the hydraulic machinery. The motions will be slow, and as the machinery for doing this is necessarily cumbersome it will not be definitely decided until after the trial whether this gear shall be adopted in the service or not. Many other details of the *Formidable* mounting now under trial are improvements on previous patterns. For instance, the arrangements for loading the shell into the cages have been very much simplified.

It is learned that one of the novel features of this mount consists in a brush (sponge), ingeniously connected with the rammer, which, simultaneously with the loading, cleans out the powder chamber.



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TURRET MOUNT FOR TWO 12-INCH, 40-CALIBER, B. L. GUNS.

In view of the fact that the Department has decided to adopt a 12-inch 40-caliber gun for our new battle ships and monitors, the following description of an English mount for guns of this class becomes of more than passing interest, and particularly so because it differs from those of our own design in many essential details. For instance, our turrets are electrically controlled and the rammers are operated by the same power.

The annexed plate illustrates a mount for two 12-inch, B. L., Mark IX, wire-wound guns manufactured by Messrs. Vickers, Sons & Maxim. The gun is 40 calibers in length, and fires a projectile of 850 pounds with a cordite charge of 212 pounds.

The mounting is composed of the following principal parts:

1. Turntable, shell chamber, trunk, and other parts of the revolving structure.
2. Training gear.
3. The gun mounting, including elevating and sighting gears.
4. Ammunition hoisting gear.
5. The gun shield.

The turntable is built up of steel plates and angle irons, and is arranged to rotate on a live roller ring, for which suitable upper and lower paths are provided. The lower path is fixed to a structure separate from and within the barbette wall, and thereby will not be affected by any distortion of the latter.

The shell chamber is attached to the under side of the turntable and revolves with it.

The trunk is attached to the floor of the shell chamber, and revolves with it and the turntable.

The rollers are provided with flanges at both ends to take the horizontal thrust, and are bound together by a ring, to which the roller axles are secured.

The training rack is attached to the turntable and gears with the training pinions, which are actuated from below.

The turntable is arranged to be rotated either by hydraulic or hand power, and provision is made so that only one form of power can be in operation at one time.

For training by hydraulic power, two 3-cylinder hydraulic engines are provided, which may act either in conjunction or separately. They are situated in a compartment immediately below the shell chamber, and are controlled from the sighting stations.

The mounting consists essentially of a gun slide formed by a pair of girders built up of steel forgings, plates, and angles, provided at the front end with two trunnion plates and at the rear end with a pair of recoil cylinders. The gun cradle is fitted with grooves, into which the gun is securely keyed, and it is arranged to travel in the upper surface of the gun slide girders. Two trunnion brackets are provided with removable trunnion pins on which the gun slide is pivoted, and around which both gun and slide rotate when elevation or depression is given to the gun. The hydraulic running out and in cylinders are placed conveniently between the two slide girders, one at either end, and have a single ram working between them, which is secured in a simple manner to the gun cradle. This ram, which is hollow, is provided with a non-return valve at its rear end. When the gun recoils, the water in the rear cylinder is forced first through the non-return valve mentioned and passes into the front cylinder, the valve being loaded to a working pressure slightly higher than the pressure in the hydraulic main, so that when water under pressure is admitted to the rear cylinder the valve will not open. The ram will in this condition be to all intents and purposes solid, and the hydraulic pressure acting on it will run the gun out after firing. The rear cylinder is, under usual conditions, always open to hydraulic pressure, so that the gun is run out automatically to the firing position. An intercepting valve is fitted on the hydraulic connection, which effectually prevents any pressure generated in the run-out cylinder during recoil from passing into any of the hydraulic connections.

The alternative method for running the gun out after firing is purely mechanical, and consists of a train of gearing connected to racks attached to the gun cradle, worked by hand or by power from the chamber below the gun, a handwheel at the rear of the mounting serving to connect or disconnect the gear from the racks. The usual hand lever for working the gun by hydraulic power is used as an indicator or telegraph to the chamber below, so that the operation on the gun platform is identical whatever method of working the gun is employed. The same system is used with the elevating gear; two toothed arcs attached to the underside of the gun slide are moved by a train of suitable gear worked by hand and by power, also from the chamber below. With this gear, however, an ingenious system of disconnection is used, so that it is not necessary to unclutch or disconnect the arc pinions when working by the usual hydraulic service. This is so arranged that the hand power is always connected up ready for working when the hydraulic pressure is shut off from the elevating presses, but it is automatically released the instant the pressure is turned on.

Automatic sighting gear is provided on the gun mounting, and is arranged in duplicate for each gun.

For loading the gun at any angle of elevation, an arm is attached to the rear of the gun slide, and extends sufficiently far to the rear to support the rammer apparatus clear of the recoil of the gun. The apparatus consists of a rammer head with guiding stem, a chain flexible in one direction only being arranged to work over a sprocket wheel,

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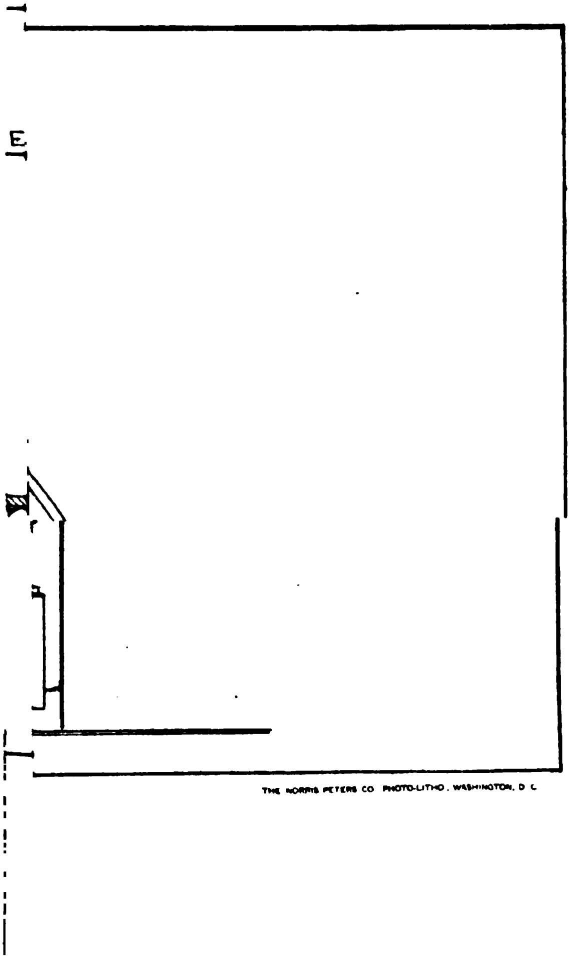

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with a hydraulic motor to rotate the sprocket wheel. This is so arranged that the rammer head is always in line with the bore of the gun. The chain is guided in a casing fixed to the underside of the slide girder and works practically without noise. To avoid shock when the rammer is withdrawn, a hydraulic buffer serves to cushion the rammer head and bring it gently to rest. A loading tray, provided on a horizontal axis below the breech, enters the gun automatically by the assistance of the ammunition cage, and is arranged to withdraw as the cage is lowered. The cage carries the usual service projectile of 850 pounds in an open tray and a service charge of 212 pounds of cordite, either in half or quarter charges, in a compartment at one side of the tray and partly above it. The cage moves up and down upon rails leading from a closed chamber below the gun. These rails, within the limits of the gun's angular movements, are concentric with the trunnions, and the cage is consequently, within this limit, always in the same line as the bore. It is arranged to abut against fixed stops on the arm attached to the gun slide by an ingenious system of simple hydraulic press connections, and when in this position it is always compelled to follow the movement of the gun. It is, moreover, locked in this position by an automatic bolt as soon as the rammer head begins to move forward, and continues so until the rammer is completely withdrawn. When the cage is in the lower position for charging in the chamber below, it is locked to the ship's structure, all slackness of the hoist ropes being completely avoided by the system of hydraulic press that has already been described.

The mounting is inclosed by a shield securely attached to the upper floor of the turntable by suitable plates and angles. The front and sides are sloping and circular in plan. The rear part is extended to provide space for the gun's crew, and also serves to balance the mounting. The opening between the shield and the barbette wall is made water-tight by means of a flexible leather apron, which may be adjusted by means of screws.

There are two sighting hoods and one lookout hood at the rear.

The principal advantage claimed for this mounting is that the gun can be loaded in any position of elevation or depression, either with the gun at rest or in motion. The gun can always be kept pointed at the target, as it is not necessary to alter its position, either vertically or horizontally, in order to load. In other words, the weapon is not brought back after firing to a fixed loading position, as has heretofore been the case, and the time required to load is therefore materially reduced.

Under date of April 24 last appears a report to the effect that, during the tests to which this mount has just been subjected, "two rounds were fired in fifty-one seconds."

FRENCH TURRET FOR 340-MILLIMETER GUN.

The annexed plate illustrates the turret mechanism for a 340-millimeter (13.386-inch) gun of the French battleship *Marceau*, constructed in the artillery department of the Société des Forges et Chantiers de la Méditerranée, Havre, before its acquisition by Schneider & Co.

This mount differs from anything of the kind that we have in our own service, in so much that the turret armor is built into the ship and remains stationary.

The gun is connected with the movable carriage, which constitutes the mounting proper, by a tongued and grooved ring which surrounds the breech end. The carriage rests on shoes forming clamps on the side paths of the main beams of the mounting, which consists of two vertical parallel cheeks, strongly stayed together. The recoil is taken up by two hydraulic cylinders, which act at the same time as controllers in returning the gun to battery. The whole system rests upon a movable platform to which is connected the vertical tube through which the ammunition is hoisted. This tube extends through the protective deck and to the magazines. Figure 4 (a horizontal section through A B, fig. 2) illustrates the hydraulic cylinders, which, by means of a plate chain, rotate the gun and its platform. The gun mounting and its mechanism is protected by fixed armor, and also by a high structure which turns with the movable platform. The gunner's stage, surmounted by a light shield, is shown in figs. 1 and 2.

For elevating the gun, the slide pivots round its trunnions in front, the trunnion plates being fixed to the movable platform; the latter rests, with the interposition of a ring of rollers, on the fixed circular path bolted to the upper deck. Elevation is obtained by means of a hydraulic cylinder, the piston of which, placed under the slide, causes the whole of the mounting to rise or fall; a valve chest with a lever, within easy reach of the gunner, is suitably arranged for obtaining the required actions. The lateral training mechanism consists of a toothed ring fixed on the tube (see fig. 4) and surrounded on half its circumference by a plate chain. Pulleys are mounted on the ends of the piston rods of the two hydraulic parallel cylinders, and around these pulleys the chain passes. When one of the cylinders is opened to the pressure, the other is free to the exhaust; so that when one ram is protruded, the other is withdrawn to an equal amount. Lateral training, therefore, is obtained by putting one or the other of the two cylinders in connection with the accumulator, according to the direction of rotation required. The valves are worked by a handwheel controlled by the gunner; a special mechanism operated by the same handwheel causes a continuous revolution more or less quick, one way or the other; the rotating movement stops when the handwheel is released.

For loading, the gun is elevated to its highest angle. In this position its center line corresponds to that of a hydraulic rammer, with

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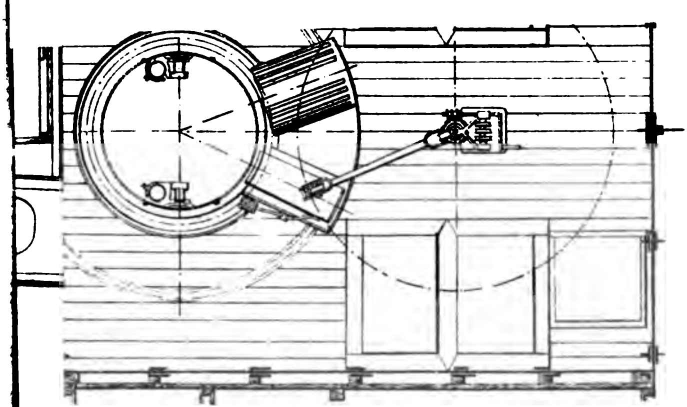

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a telescopic ram carried on the turret platform; this rammer serves to drive home the projectile and the two half cartridges. The charge holder is of the same form as that already described; it has three tubes mounted on an axle, placed, when in position for loading, at the same angle as the gun; a partial rotation through 120 degrees brings the projectile and the two half cartridges successively opposite the breech; an automatic latch bolt fixes the barrel in the required positions. The charge holder is worked by two hydraulic pistons, the cylinders of which are placed vertically in the tube, near the guiding slides. The two plate chains are fixed at one end to the head of the piston rods and at the other to the plate which supports the charge holder. The plate is also guided by two slide shoes which travel in the slides fitted to the tube. The charge holder is mounted on a truck which renders it movable in its support and which is fitted with two rollers that travel in vertical slides; these are made to branch off at their top part. This arrangement forces the truck to travel first vertically, and when it nears the breech to slide back so as to take up a suitable position for the loading of the gun. At the lower staging the operations follow each other thus: Cranes raise the projectiles and half cartridges to the height of the lower deck, from where they are taken by a set of tackle that travels on a circular line made concentric with the ammunition tube. The tackle discharges in a cradle fitted to the lower part of the tube; the charges have then only to be slid in their compartments in the barrel. The gun can be loaded, whatever be the position of the firing platform.

NAVAL MORTARS.

M. de la Porte, deputy, in his report on the general budget of the minister of marine for 1900, states that, in his opinion, France's objective in a naval war would be double, first, the mobile defenses of the coast combined with an offensive, within a small radius of action, by means of torpedo boats and submarine boats perhaps assisted by *mortar gunboats;* and, second, commercial war carried on by numerous rapid cruisers of a great radius of action. He hopes that the experiments made with the *Dragonne* as a mortar gunboat will be successful.

This calls attention to a type of naval weapon, a breech-loading mortar, designed by the Schneider-Canet Company, for installation upon *avisos-mortiers*, should the French Government decide to build vessels of this class.

Figures 1 and 2 illustrate a 15-centimeter (5.905-inch) breech-loading mortar on a central-pivot mount, some of the elements of which are as follows:

Weight of mortar	480 kilograms (1,058 pounds).
Weight of mounting	2,700 kilograms (5,950 pounds).
Weight of projectile	40 kilograms (88 pounds).

Muzzle velocity in service	200 meters (656 feet).
Elevation	-5 degrees + 60 degrees.
Training	360 degrees.

The gun is fitted with a breech mechanism of the two-action type. To the rear is screwed a recoil jacket to which is attached the head of the hydraulic recoil piston. The housing is provided with trunnions, and consists of a cylindrical body in which the mortar slides and of a hydraulic recoil cylinder with constant resistance. The piston is held by the recoil jacket, and a counter rod is provided of a slightly larger diameter, which, by penetrating into the cylinder during recoil, forces part of the liquid to flow into the recuperator. The latter is placed outside of the right slide bracket and consists of a vertical cylinder in which moves a double diaphragm, combined with a set of springs. Communications between the recuperator and the recoil cylinder is made by a pipe passing through the right trunnion of the housing. A loaded valve placed on this circuit is raised as the gun recoils and it falls back in its seat as the recoil is spent. The liquid returns by flowing through small vents cut in the valve seat, and the mortar runs out slowly under the relaxing of the recuperator springs. To the left side of the recoil cylinder is attached the rack for elevating the mortar.

The slide consists of two brackets, with stiffening ribs, strongly bolted together. Its lower part forms a circular plate, round which is the racer which carries the balls for facilitating the rotary movement; in its center the plate is in the shape of a vertical cylinder which fits on the fixed pivot of the bolster. The slide is provided with lugs and clamps for setting the mechanism in any position. The bolster, on which the slide rests with the interposition of the set of balls, is fitted with a circular rack for training the weapon and with a ring plate in the holes of which the foundation bolts are placed. Its central part forms the fixed pivot.

A handwheel for elevating the gun is on the left of the slide. It is trained by a second handwheel slightly to the rear of the preceding one.

This mount takes up but little room.

Figure 3 illustrates a 22-centimeter (8.661-inch) mortar, the principal elements of which are as follows:

Weight of mortar	3,500 kilograms (7,714 pounds).
Weight of mounting	11,600 kilograms (25,566 pounds).
Weight of projectile	116 kilograms (255 pounds).
Muzzle velocity in service	300 meters (984 feet).
Elevation	—5 degrees + 60 degrees.
Training	360 degrees.

The official report of the firing trials of the *Dragonne*, with a mortar of the type described, has not been published. It is stated, however,

Fig. 1

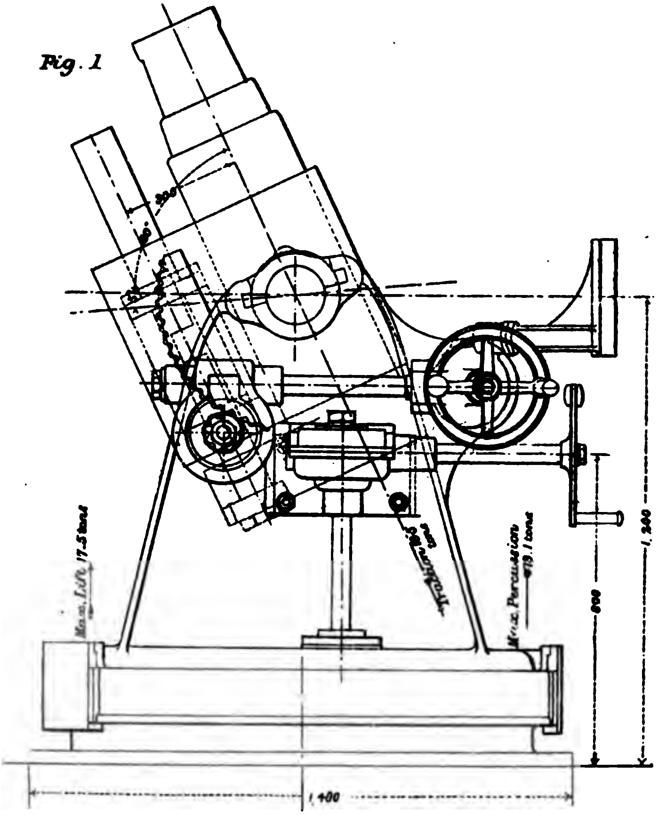
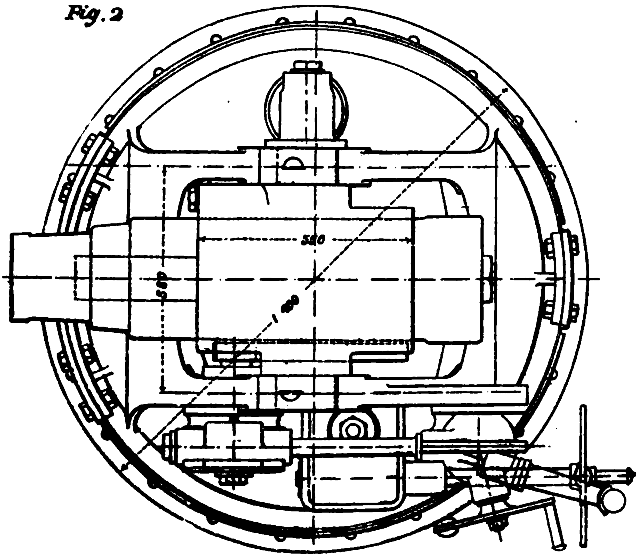


Fig. 2



FRENCH NAVAL MORTARS.

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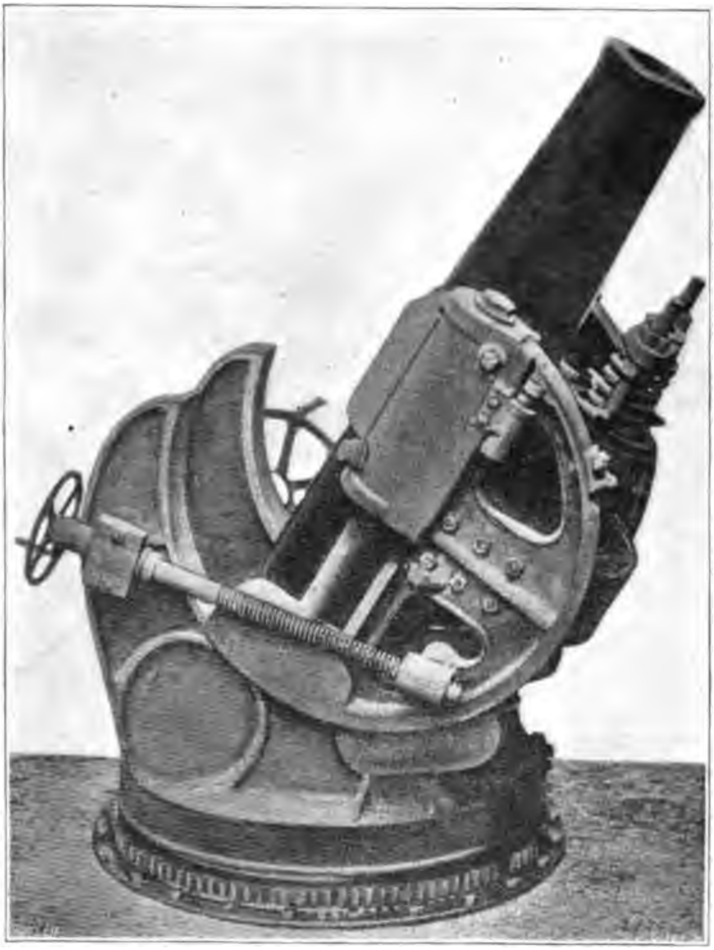

Fig. 3.—FRENCH NAVAL MORTAR.

Cap for
French Armor-Piercing
Shell

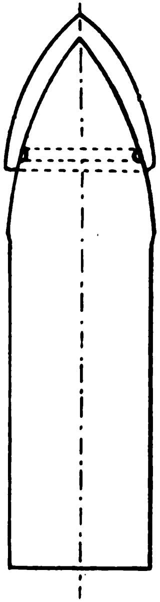

Fig. I.

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Cap for Melinite Shell

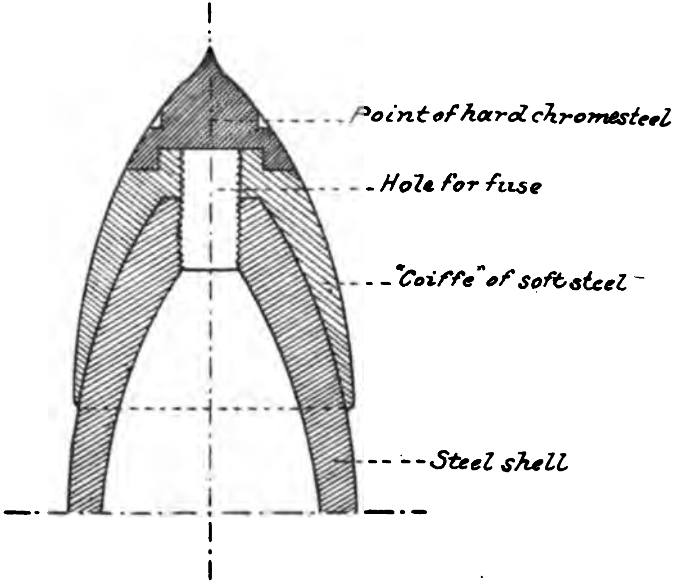

Fig. II.

that two series of experiments were conducted, the first, at 5,200 meters, against an elevated battery; and the second, at ranges varying from 1,500 to 300 meters, against an old hulk, the *Panama*, which was hit once on the water line, at a distance of 400 meters.

PROJECTILES.

With each radical change in the method of manufacture of armor plate by which, by various face-hardening and toughening processes, its resisting power has been greatly increased, we find an effort made to produce a projectile that will attack it successfully. These efforts have not been wholly unsuccessful. In distributing the credit, however, for the most recent performances of projectiles against face-hardened armor, the great increase in the energy developed by the latest type of the modern rifle must not be forgotten; and, if practicable, the proper share of the work done by the gun should be assigned to it. Leaving the gun out of the question, the effectiveness of armor-piercing shell has been greatly increased by the so-called cap, which is secured to the ogive to protect it upon impact with the hard surface of the plate. Experiments have proven that with capped projectiles, the velocity remaining the same and with the impact normal to the plate, an increased thickness of from 15 to 20 per cent of metal may be perforated. Various reasons have been given for this, the most acceptable being that the initial shock is given the plate by the soft cap, which, while it protects the hard point of the projectile, weakens the hard surface of the plate and prepares it in a measure for the entrance of the projectile proper. Caps seem to be gaining more and more in favor and are now used in the navies of Russia and France as well as our own. There is an objection to capped projectiles which it may be well to mention. In case the cap should become detached from the projectile while the latter is still in the bore there is great danger of the gun bursting. Effective means can of course be used to secure the cap firmly, but when the manufacture is carried out on a large scale it is difficult to obtain full guaranty in this respect.

The cap of the French naval shell is put on in a heated state. It extends down over three-fifths of the ogive, as shown in figure 1.

The type of projectile which was formerly in common use, the cast-iron shell, has, owing to the general introduction of secondary armor, lost much of its importance. A steel shell has taken its place. This is called a semi-armor-piercing shell; it has a solid point and a percussion base fuse. This projectile, owing to its comparatively strong construction, possesses a power of penetration estimated at three-fourths of the armor-piercing shell. Its effectiveness is increased by the large bursting charge. The absence of a bursting charge from the armor-piercing shell makes the latter a special projectile.

Every effort is being made to construct a type of shell that will burst *after* penetrating modern armor of comparatively great thickness. This is the ideal missile.

In France attempts have been made to increase the effect of a bursting shell against armor by providing the ogive of the former with an ingeniously constructed cap. This (*see* fig. 2) consists of two parts, one of soft steel, which is screwed to the ogive and has a screw-threaded hole into which the fuse is screwed, and a point of hard chrome steel, which is screwed to the outside of the soft cap. Whether or not this cap accomplishes the desired effect does not seem to be generally known.

The destructive effect of a bursting shell depends on the power of the explosive it contains.

The high explosives now employed are usually of a picric-acid preparation or of wet gun cotton. To the former type belong the English lyddite, the French melinite and kresylite, and the Austrian ekrasite. In Germany and Italy a wet gun cotton is used. That melinite is regarded by the French as sensitive and dangerous is evidenced by the minute regulations which have been issued for its care and handling. Lyddite, used in the English high-explosive shell, is claimed (by the English) to be safer and more powerful than melinite. It is simply picric acid brought into a dense state of fusion. The shells are coated inside with a special varnish and the melted acid poured into them. This requires a strong detonator or, in other words, a powerful primer. It is said that the English have adopted a primer of picric powder, which consists of two parts of ammonium picrate to three parts of saltpeter, mixed in much the same way as ordinary granulated gunpowder. The composition is ignited by the usual service fuse. Lyddite was first used in actual warfare at the battle of Omdurman, where its effects are reported to have been terrifying; the mere shock of the bursting of a shell killing or disabling anyone within a radius of 40 or 50 yards. If recent reports from South Africa about the lyddite shell be true, the area of its destructive power has been greatly exaggerated. In this connection it may be well to state that lyddite, like all other of the so-called high explosives, is more or less unreliable. When its combustion has been complete a black smoke is given off, but when fumes of a greenish hue are seen to arise, it is a sign of incomplete combustion, and, in consequence, that the force of its explosion has been considerably reduced. The English authorities apparently have great confidence in lyddite. When used against field artillery and bodies of troops in the open, the moral effect of lyddite shell is enormous.

Figure 1 is a section of a cartridge case for an English 3 or 6 pounder R. F. gun. The charge consists of a bunch of cordite folded back, as indicated in the illustration. A small black-powder charge, contained in a bag, is attached to the cordite and serves as an intermediary

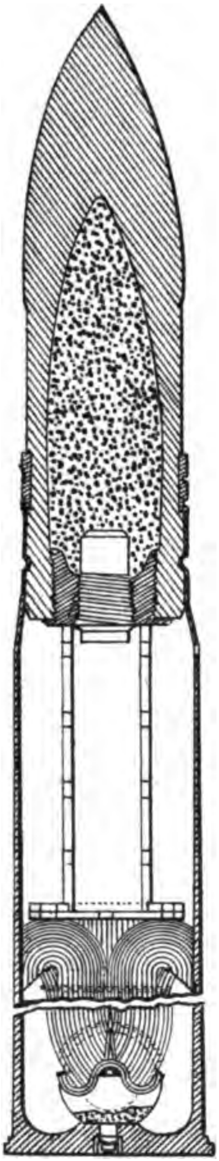

Fig. 1.

3 and 6 Pdr. R.F. Cartridge Case.

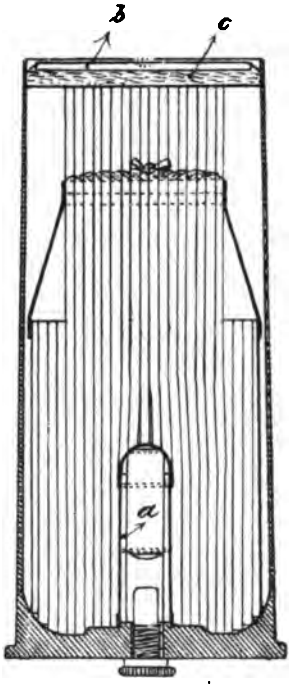

Fig. 2.

6 inch Cartridge Case.

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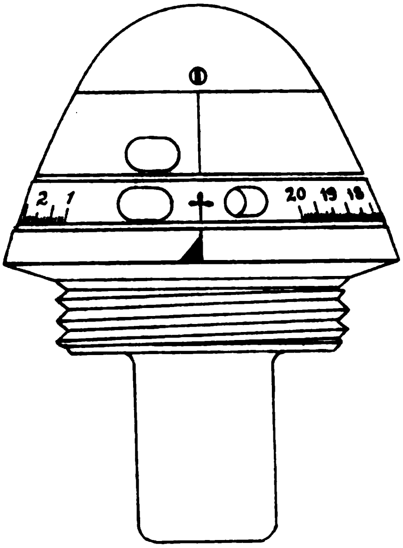

Fig II

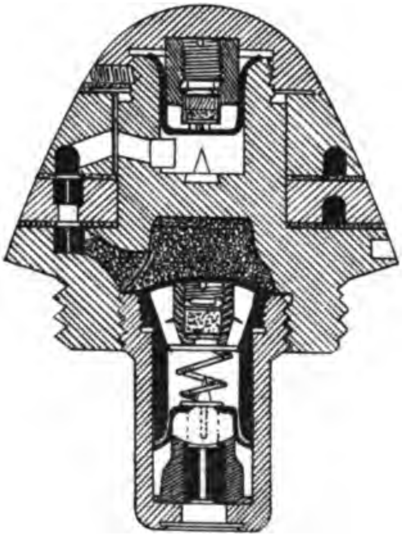

Fig III

Scale 1/1

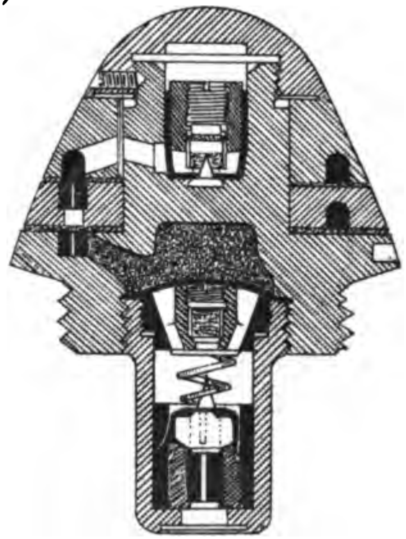

Fig IV

Fuse for Krupp 7.5 c.m. Field Gun Shrapnel.

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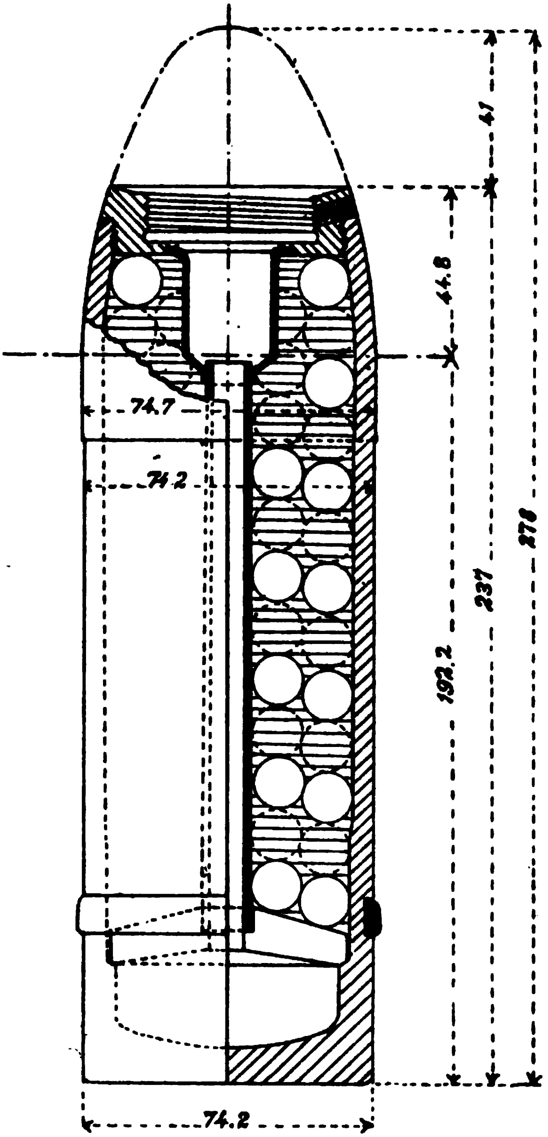

Krupp 7.5 c.m. Field Gun Shrapnel.

Fig. I.

Scale ½.

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between it and the primer. A pasteboard cylinder is placed between the projectile and the charge and holds the latter against the base of the cartridge case.

The cases for the 12-pounder, 4.7-inch, and 6-inch R. F. guns have at their base a hole into which is screwed a carrier to receive the percussion cap.

Figure 2 represents a 6-inch cartridge case charged and primed. The cordite arranged in bundles is partially enveloped in a bag. The 4.7-inch case is arranged in the same manner. In these cases the cartridge bag has a pocket at the bottom which receives the black-powder charge, inclosed in a small bag and surrounded by a cylinder of cordite, *a*. The cases are closed by a white-metal cover, *b*, formed of two soldered disks, between which a lubricating substance is introduced. A felt packing, *c*, is interposed between the charge and the cover.

Figure 1 is an illustration of a shrapnel for Krupp's R. F. field gun, caliber 7.5 centimeters, model of 1899. It is a steel base-chamber projectile, in which hard-lead bullets are secured in position by an infusion of rosin. The inner face of the steel core has at the front end a screw thread for the fuse-hole box, which is kept in position by a rivet screw. The inner screw thread of the fuse-hole box receives the screw plug, while its forward cone-shaped recess acts as a base for the lower face of the fuse plate. The centering of the projectile is accomplished in front by a slightly arched pad and at the rear by a copper ring, the profile of which in its forward part is also slightly arched. The bursting charge consists of fine-grained black powder.

The fuse (*see* figs. 1, 2, and 3) is a combination time and percussion fuse, similar in its action to the one in use in our own service. The peculiar feature of this fuse rests in the fact that all of its larger metal parts are of aluminum alloy, and in consequence it is very light.

The brass cartridge case is of the usual shape, slightly conical and tapering at the forward end, with projecting base rim, screw plug, and cartridge cup.

The powder used is Düneberg tubular powder (German patent) of the Cologne-Rottweiler powder factories. As to its chemical composition, it belongs to the nitroglycerin powders.

DATA.

1. Shrapnel:
   - Length without fuse, 23.70 centimeters, 3.1 calibers.
   - Length with fuse, 27.80 centimeters, 3.7 calibers.
   - Distance of rear edge of centering ring from surface of base 3.80 centimeters.
   - Distance of bottom of ogival point from surface of base, 19.22 centimeters.
   - Distance of bottom of ogival point from point of fuse 8.58 centimeters.
   - Maximum diameter of centering ring, 7.80 centimeters.
   - Diameter of steel core at centering pad, 7.47 centimeters.
   - Diameter of steel core at cylindrical part in rear of centering pad, 7.42 centimeters.
   - Weight of empty steel core, 2.600 kilograms.
   - Weight of charged steel core 6.145 kilograms.

1. Sharpnel—Continued.
   Weight of bursting charge 0.075 kilograms.
   Weight of double-acting fuse S/20, 0.280 kilograms.
   Weight of projectile ready for firing, 6.500 kilograms.
   Weight of bullet filling, 3.245 kilograms.
2. Cartridge case:
   Length, 27.80 centimeters.
   Outer diameter immediately forward of base rim, 8.05 centimeters.
   Diameter of projecting rim of base, 9 centimeters.
   Thickness of projecting rim of base, 0.35 centimeters.
3. Cartridge:
   Length, 51.8 centimeters.
   Depth to which the projectile enters the cartridge case, 3.8 centimeters.

Figure 3, illustrates the form of cap now being manufactured by the Hotchkiss Company in Paris for the 100-millimeter armor-piercing shell. The metal is furnished the company in the shape of bars; they turn it into shape and chill the heads. The cap is made of mild steel of a tensile strength of 45 kilograms per square millimeter of section. The cap is attached to the projectile by being shrunk into the groove A. Before placing the cap on the ogival head, both the interior of the cap and the exterior of the ogival are turned accurately to the same dimensions. This being not always possible, a lot of shell after being completed are carefully calipered and divided according to dimensions into four sub-lots. The same is done with the caps.

To secure the cap in place it is heated to nearly a red heat and slipped over the shoulder at A, after which a jet of water plays on the cap at B, shrinking it into place. The heads of the caps down to the dotted lines indicated by D′D′, are tempered, though the steel is so mild that it will not take much temper. The caps must fit the shell so accurately that when tapped with a hammer they give out the same sound as the body of the shell; in other words, the cap must grip the shell over all points of the ogive. The groove A, into which the cap is shrunk, has no sharp angles or shoulders, but it is a smooth curve, as more clearly shown in the larger sketch to the left. The depth of the groove A is not more than 1 millimeter. The thickness of the metal of the cap at B, just above the groove, is 2.5 millimeters, and the thickness of the cap from the point of the ogive to its point—that is, from E to F—is 26 millimeters.

The tests for the uncapped shells are as follows:

A shell is selected from a lot of 1,000 and fired at an unhardened plate of 12 centimeters steel. The angle of impact is 18 degrees from the normal, and all pieces of the shell are required to pass completely through the plate.

The tests for the capped projectiles take place under the same conditions, except that the plate is of 12-centimeter Harveyized steel. The shell must successfully pierce this plate at an angle of 18 degrees.

Mild Steel Cap

French Armor-Piercing Projectiles

PLATE.

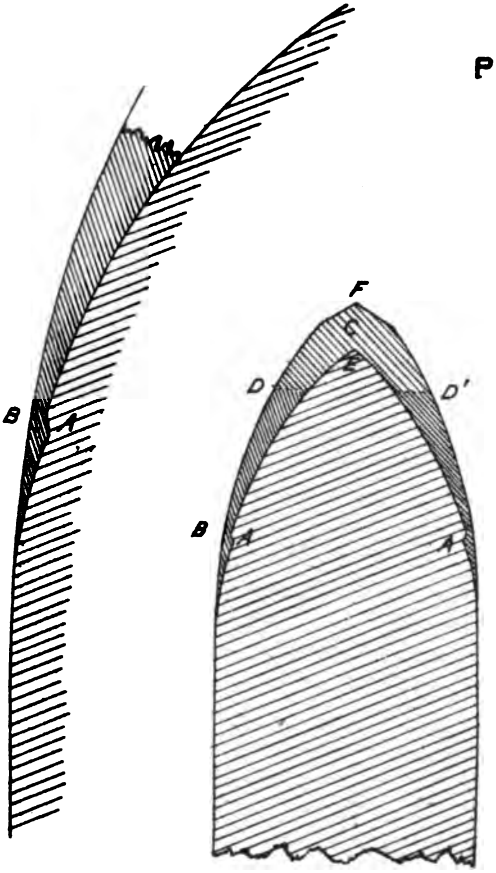


Fig. 3.

THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

If a shell fails to pass the test the company can, by special permission of the Government, retemper the lot and be given a new trial.

If a shell passes whole through the plate the company is paid a premium of 10 per cent on the contract price. If the shell breaks into two pieces the premium is about 9 per cent, and if into more than two pieces the premium is reduced.

It is understood that all armor-piercing shell in the French navy up to 16 centimeters are now capped in the same manner as the projectile described above.

A German method of securing caps to armor-piercing projectiles is by means of soft solder. The latter has a comparatively low melting point, less than 200° C. The cap and the point of the projectile are immersed in the solder until both parts are heated to its temperature and are completely coated. The point of the projectile is then pressed into the cup of the cap and the surplus solder forced out.

SMOKELESS POWDERS.

The British Admiralty has just appointed a committee to inquire, in an absolutely independent manner, into possible improvements in explosives. The committee is to conduct trials with a view to discovering what are the best smokeless powders for use in guns of all calibers, as well as in small arms, and to report whether any modifications in existing designs of guns are desirable, in order to develop the full powers of any powders that may be proposed. The organization of a board with such full powers should not be construed as meaning that the English have lost confidence in cordite, but simply that they do not consider the manufacture of smokeless powders to be a finished art; and that, like the rest of the powers, they are looking for a substance that will produce equal, if not better, ballistic results without erosion. The English, after exhaustive experiments with a brown prismatic powder, succeeded in determining the number of rounds for each caliber that can be fired from a gun before precision is lost to be as follows:

Caliber in inches.	Number of rounds.	Caliber in inches.	Number of rounds.
4	739	10	162
5	640	12	149
6	395	13.5	102
8	254	16.3	83
9.2	204		

NOTE.—In the light of our own experience these figures are much too low.—O. N. I.

Lieutenant-Colonel Delauney, of the French army, through a study of the above figures, deduces a law which he expresses as follows:

> The square of the number of rounds which a gun can be fired before it loses its precision, in consequence of erosion, is in the inverse ratio to the cube of the caliber.

The Colonel claims that the erosion which threatens the life of modern guns is produced, not by modern powders nor through lack of hardness of the metal of the gun, but by the space which is between the exterior of the band on the projectile and the walls of the bore of the gun, through which the gases escape at a very high temperature (higher in powders which contain nitroglycerin) and as a consequence produce erosion. This air space naturally becomes enlarged until a time arrives when the fire loses all precision, and it is necessary to restore it in part by exchanging the band of the projectile for another of larger diameter.

The following notes on smokeless powders, extracts from a lecture delivered by Captain Grahm before the Royal Naval Society of Carlskrona, contain the results of tests of the powders used by a number of the European powers. To those wishing to make comparisons, these tests are of more than passing interest, for, as their author is a recognized authority upon ordnance matters, there is every reason to believe that the data they contain are accurate.

> In the Russian navy, after lengthy and thorough trials, a powder containing no nitroglycerine has been adopted, known as pyrocollodium powder. It consists principally of nitrocellulose with a low percentage of nitrogen, and has shown very good and even results at firing trials. The reason why this was chosen in preference to a powder of the ballistite type—that is to say, containing nitroglycerine—was not because the advantages of the latter were not recognized, but because it was impossible to overcome the erosion caused by the excessive heat. Pyrocollodium powder is now being manufactured for all calibers in the Russian navy. Nevertheless a large quantity of ballistite has recently been purchased from German factories.
>
> A similar powder containing no nitroglycerine, manufactured for the Danish navy, has also shown good results. The following table contains data of firing trials which took place on August 10, 1899.
>
> Proof firing of a 15-centimeter Bofors R. F. gun of 43-caliber length, for Danish ironclad *Herluf Trolle*. Kind of powder used, Danish gun-cotton powder:

Weight of projectile.	Weight of charge.	Pressure in atmospheres.	Initial velocity.
Kilograms.	*Kilograms.*		*Meters.*
51	9.5	2,225	697
51	9.5	2,295	698
51	9.5	2,375	695
51	9.5	2,295	695
51	9.5	2,347	696
Average ... 51	9.5	2,307	696

Results of test of French smokeless G. C. powder 13, in 25-centimeter gun M/94, at Carlskrona March 15, 1899:

Weight of projectile.	Weight of charge.	Pressure in atmospheres.	Initial velocity.
Kilograms.	*Kilograms.*		*Meters.*
204	52.65	2,076	743.3
203.5	52.65	2,172	750.8
203.5	51.50	2,017	726.5
203.5	51.50	2,059	732.9
Average, 203.6	52.10	2,061	738.2

Results of tests of 3-millimeter Swedish Nobel powder type IV (manufactured by the Bofors Company) in 25-centimeter gun M/94, at Bofors:

FIRST TRIAL, GUN NO. 5, MARCH 17, 1899.

Weight of projectile.	Weight of charge.	Pressure in atmospheres.	Initial velocity.
Kilograms.	*Kilograms.*		*Meters.*
204	45	1,930	727.5
204	45	1,998	729.9
204	45	1,962	726.0
Average.. 204	45	1,963	727.8
SECOND TRIAL, GUN NO. 6, MARCH 29, 1899.			
Kilograms.	*Kilograms.*		*Meters.*
204	45.5	2,003	727.4
204	45.5	2,021	732.9
204	45.5	1,994	731.5
Average.. 204	45.5	2,006	730.6

A comparison of these results of French smokeless G. C. powder 13 and Nobel powder type IV shows much greater uniformity in the Swedish article. Moreover, Nobel powder IV, with a pressure of about 100 atmospheres less than in the case of the French powder, has shown the effect to be 122 mt. per kilogram of powder, while that of the French powder was only 108 mt. per kilogram. It must be admitted that the working pressure employed in the case of G. C. powder 13 was not nearly so high as it should be in order to attain the best results (about 2,300 atmospheres); but the ballistic superiority of the Swedish powder is nevertheless apparent. As in addition thereto no erosion was noticeable, in spite of the comparatively large number of rounds fired during the trials, it was decided to adopt Nobel powder IV for the 25-centimeter guns of the *Oden* as well as the *Thor* and *Niord.*

Nobel powder is also to be tested in Sweden for 21 and 24-centimeter guns.

Another type of smokeless powder is manufactured at the Government works at Åker. It is one of the types containing no nitroglycerine (Troisdorf type). Comparative tests of Nobel and Åker powder were made at Carlskrona January 24 and 25, 1899. In a 57-millimeter R. F. gun M/89 B, with a charge of tube-shaped Åker powder weighing 560 grams, an initial velocity of 710 meters was attained, with a pressure of 1,981 atmospheres, while Nobel powder (in grains) showed about the same velocity with a charge of only 405 grams.

Troisdorf powder manufactured at Åker has also been tested in a 12-centimeter R. F. gun intended for Oscar-Fredriksborg. The interior construction of this gun is the same as that of the 12-centimeter R. F. naval gun, and as the volume of the powder chamber is rather small for the Aker powder, which requires larger charges than Nobel powder for the same effect, it could hardly be expected that the initial velocity would be as great as in the case of the naval gun (740 meters). These trials took place on September 28, 1899. The Åker powder employed was tube shaped; length of tubes, 454 millimeters; effect per kilogram of powder, 111 mt.

The following table (giving the seventh to fourteenth rounds) shows the results of these trials:

Weight of charge.	Weight of projectile.	Pressure in atmospheres.	Initial velocity.
Kilograms.	*Kilograms.*		*Meters.*
4.8	21.2	2,304	747.3
4.8	21.2	2,120	708.3
4.8	21.2	1,847	684.9
4.8	21.2	2,058	712.8
4.8	21.2	1,945	710.3
4.8	21.1	2,090	719.2
4.8	21.2	1,984	702.5
4.8	21.2	2,032	699.2
Average .. 4.8	21.2	2,048	710.6

The most noteworthy feature of these results is the great difference in velocities, which exceeds the difference which is usual in the case of Nobel powder type IV.

A quantity of English cordite powder has been purchased for the large caliber fortress guns at Oscar-Fredriksborg. Tests made with this powder on December 12, 1898, in a 24-centimeter gun M/92 (volume of powder chamber, 136 liters), have given the following results:

Weight of projectile.	Weight of charge.	Pressure in atmospheres.	Initial velocity.
Kilograms.	*Kilograms.*		*Meters.*
215	36	1,742	599
214.5	38	1,978	637
215	38	2,029	635.5
214.6	38	2,013	633.4
Av. of last 3 rounds 214.7	38	2,007	635.3

Another interesting firing trial took place at Carlskrona September 6, 1899, for the purpose of determining the ballistic effect that can be attained with Nobel powder in a 15-centimeter gun M/89 with decreased powder charge. The volume of the powder chamber was decreased by introducing a metal case of a volume of 6.5 liters into the powder chamber, thereby reducing its volume to 18.3 liters. The type of powder used, size 16 by 9 by 112 millimeters, was that adopted for the 12-centimeter R. F. gun M/94. The results are shown in the following table:

Weight of projectile.	Weight of charge.	Pressure in atmospheres.	Initial velocity.
Kilograms.	*Kilograms.*		*Meters.*
45.4	9	2,382	743
45.4	8.5	2,128	710
45.4	8.35	2,135	703
45.4	8.1	2,021	688
Av. of last 3 rounds. 45.4	8.32	2,095	700

It will be seen that with this powder an initial velocity of 700 meters can be attained, with a pressure not exceeding 2,100 atmospheres, while with the older charges, the weight of which was nearly three times as great, only 630 meters initial velocity could be reached. This shows that by converting the type of gun in question good results could be attained from a ballistic standpoint.

As to the price of smokeless powder, the general impression prevailing is that it is very much more expensive than the older kinds of powder. But this is not the case when we take into consideration the effect of the different kinds. For instance, a charge of brown powder for a 25-centimeter gun M/94 costs 5.2 öre (1.39 cents) per mt. of muzzle energy, while the corresponding price of Nobel powder IV is 6.6 öre (1.76 cents).

RANGE FINDERS.

Although officers of experience have claimed that the best range finder in action is a 1 or 3 pounder R. F. gun in the hands of an expert marksman, the value of an instrument that will quickly and accurately measure the distance of an object can hardly be overestimated. The fact that there is a demand for an instrument of this character is indicated by the various patents obtained for inventions in this field. Few of these, however, are suitable for naval purposes. They are nearly always of delicate construction and liable to get out of adjustment at the moment of critical need. Range finders may be divided into two general classes, those which are fixed—that is, mounted upon stands—and those which are portable. Both have their uses on board ship.

THE BARR AND STROUD RANGE FINDER.

This instrument has been adopted by the British admiralty and is also used in the navies of Austria, Japan, and other foreign powers. One has just been placed on board the *Albany* for trial.

A full description of the special features claimed for it, its principle, construction, and the various uses to which it can be applied are therefore given.

SPECIAL FEATURES OF THIS RANGE FINDER.

1. It occupies very little space.

2. It requires only one observer, and thus avoids the necessity for communication between men at different stations, and the consequent danger of errors.

3. The ranges of any objects visible from the range finder can be taken quite irrespective of their bearing or altitude.

4. The operation of the instrument is so exceedingly simple that no difficulty is found in using it successfully after a few minutes' trial.

5. Its standard of accuracy is very high—higher, it is believed, than that of any other range finder.

6. The indications depend solely upon the base length, the angle of

a deflecting prism, the focal length of the objectives, and the graduations of the scale. There are, therefore, no parts the wearing of which can cause the instrument to give erroneous readings.

7. It is particularly free from liability to derangement.

8. If deranged it can readily be readjusted.

9. It is capable of standing all ordinary usage without derangement, and is in no way affected by the shock of gun fire.

10. The arrangements for "finding" the object, aligning the images, and reading the scale are such that it is found possible to accurately determine the range of an object in from eight to twelve seconds from the time the observer reaches the instrument.

11. The arrangement for reading the scale enables a moving object to be kept constantly in view and its range taken as frequently as desired.

12. When observations have to be made in rapid succession the eyes need not be taken from the instrument. This avoids exposure of the eyes to strong light, which would render them for some time incapable of making delicate telescopic observations.

13. The distance of a light can be taken at night as easily as the distance of a ship or other object can be determined during the day.

14. The instrument can be rapidly dismounted and again erected, or changed from one position to another, without any of its adjustments being affected.

15. The instrument is always ready for use; there are no preliminary adjustments necessary.

16. As mounted on board ship it is the most convenient and accurate instrument yet invented for navigational distance finding, both by day and by night.

17. For use as a fortress range finder it may be placed close to the water level or at any convenient altitude, and requires no adjustment for height above sea level or for changes of tide.

PRINCIPLE OF THE INSTRUMENT.

(See Plate I.)

Fig. 1 is a diagrammatic representation of the instrument, details of construction being omitted for the sake of clearness in the explanation of the principle of operation.

Two beams of light from the object viewed are received by the reflectors, and transmitted through the objectives towards the centre of the frame, where an arrangement of prisms is placed to reflect the beams outwards through the right eye-piece. By these means two partial images of a distant object are seen, one over the other, as shown in fig. 9, the image seen in the upper half of the field of view of the right eye-piece being formed by the equivalent of a telescope directed towards the object from the right-hand end of the instrument, the image seen in the lower half being formed by the equivalent of a second telescope directed towards the object from the left-hand end.

The images are seen separated by a thin black line, as shown in figs. 8 and 9. This line is called the "separating line."

Suppose a very distant object is viewed by rays shown at L_1 L_2 (fig. 2), and that the partial images of that object are seen in correct coincidence as illustrated in fig. 8. If, now, the object approaches the instrument along the line L_1, the beam of light received by the right-hand reflector will take a different direction, such as is shown by the line L'_2, and the partial images will no longer appear in proper coincidence, but will occupy such relative positions as are shown in fig. 9. (The relative position of the images is not affected by any turning of the instrument in azimuth; the images move together across the field.) The partial images might be brought together by rotating one of the reflectors, but the necessary rotation would be almost infinitesimal, and would consequently require to be made and indicated with excessive delicacy.

The bringing of the two partial images into coincidence is effected in this range-finder by means of a "deflecting prism" of small angle (fig. 1), which is placed in the path of the rays from the right-hand reflector and is movable longitudinally in the tube. The action of this prism in producing coincidence is illustrated in fig. 3. The partial images of a very distant object are in coincidence when the deflecting prism is in position N, but the prism has to be moved to the position O in order to bring the partial images of a near object into coincidence.

As usually constructed, a motion of the prism of about 6 inches (150 millimeters) corresponds to a change of range from infinity to 250 yards (or meters).

An ivory scale (fig. 1) is attached to the refracting prism carrier, and on it the distance of the object viewed is read by aid of a scale lens in the left eyepiece, the scale being graduated to give the distance directly in yards or meters, or any other unit.

It should be particularly noted that since the scale is attached to and moves with the deflecting prism slackness or irregularity in the gear by which the scale is moved produces no error in the indications; *and therefore no amount of wear can affect the accuracy of the instrument.*

CONSTRUCTION OF THE INSTRUMENT.

(See Plate I.)

Externally the range-finder consists of a double tubular case about 5 feet (1.5 meters) in length and 3½ inches (9 centimeters) in diameter, shown in figs. 1, 4, and 5.

A frame (fig. 1) carries all the optical parts of the instrument with the exception of the eyepieces, finder-objective and windows.

This frame is carried within the tubular case on two supports which are so arranged that no deformation of the framework can result from the application of forces to the case.

Each range-finder is thoroughly tested for temperature effects and is compensated, if necessary, to provide against errors due to this cause. Differential heating of the frame would cause it to bend, and the readings of the instrument would thereby be affected. Errors are entirely prevented by the peculiar form of the frame and by constructing the outer case of two tubes, one inside the other. This greatly retards the transmission of heat to and from the interior, and distributes it evenly around the frame.

The deflecting prism (and the scale attached to it) are moved by means of a screw. This screw is actuated by a working head (fig. 4), which is placed on the upper side of the tube in a convenient position for being operated by the observer's right hand.

The nature of the scale is shown in fig. 13, but the graduations are too numerous and come too close together to admit of the scale—as actually cut on the ivory—being represented on the drawing.

The scale is usually divided in single yards from 250 yards to 500 yards, in tens of yards to 1,500 yards, in hundreds of yards to 5,000 yards, and in thousands of yards to 10,000 yards; marks are also cut for 15,000 yards, 20,000 yards, and infinity. (Similar graduations are made in the case of meter scales.) Special modes of graduation can be adopted when required.

The centers of the eyepieces are placed at 2½ inches (64 millimeters) apart, but the left eyepiece (fig. 5) is arranged to make the instrument equally convenient for observers whose eyes are at a greater or less distance than 2½ inches apart.

The scale is read by the left eye when the images seen by the right eye have been brought into alignment. After a little practice the two eyes can be used alternately or simultaneously for their respective duties without losing the object from the field of view of the right eye while the scale is being read.

A very simple and efficient "finder" is provided to enable the observer to immediately direct the instrument upon the object. This finder consists of a small telescope of low magnifying power, the objective of which is seen in figs. 1 and 4, and which is used by the left eye, the scale occupying only a portion of the left-eye field, as shown in fig. 7. The field of view of this telescope is wide enough to enable the observer at once to "find" the object whose distance is required, and when the instrument is so directed as to bring the object into the center of the finder-field (see fig. 7), the object will be found, greatly magnified, in the field of view of the right eyepiece (fig. 8).

An india-rubber face piece (figs. 5 and 6) is fixed to the tube around the eyepieces. This, by giving a soft rest for the brow, makes the instrument more comfortable to use, especially when guns are being fired in its vicinity; it excludes light other than that received through the eyepieces, and it guides the eyes to the eyepieces in night observations when, from the small amount of light received, the eyes otherwise would not immediately find the apertures.

For taking the distances of lights at night, such as ships' lights or light-houses, an optical appliance, called the "astigmatiser," is provided in the interior of the instrument. The astigmatiser draws out each image of a point of light into a vertical streak (fig. 10), which can then be aligned exactly as the images of a mast or other object are aligned in daylight observations. The astigmatiser is put into or out of action by means of a slider (fig. 4) actuated by the thumb of the right hand.

In order to render the scale visible at night, a small electric lamp—identical with those used for the night sights of guns—is fitted on the instrument, as shown in fig. 4. A small battery may be used to supply the current, or, if preferred, the lamp wires can be arranged to lead current from a "transformer" circuit. A contact maker (fig. 5), actuated by the right hand, switches on the lamp when the scale is to be read at night.

It is found that the instrument, unless it meets with an accident, seldom, if ever, requires adjustment. Two adjustments are, however, provided for, called, respectively, the adjustments for "halving" and "coincidence."

The former is to accomplish the condition that the two partial images shall form a complete one and neither show "duplication," as illustrated in fig. 11, nor "deficiency," as illustrated in fig. 12.

The adjustment for coincidence is to accomplish the condition that the scale shall give the true distance of an object from the range finder when the partial images of that object are seen in correct coincidence or alignment, as in fig. 8.

This adjustment thus corresponds to the index adjustment of a sextant, but is not convenient to work in a range finder with an "index error," owing to the scale not being a uniformly divided one.

These adjustments are accomplished by means of two milled heads, rendered accessible by partially rotating the cover plate, as shown in fig. 4.

The "halving" adjustment can be tested by observation on any object at a distance of over 250 yards. The distance of the object does not require to be known.

The "coincidence" adjustment is conveniently tested by observation upon the moon or a star, when the reading of the instrument should be "infinity"—indicated by the star-shaped mark on the scale.

Windows of optical glass are fitted over the apertures (see figs. 1 and 4), and the outer case is everywhere so closed as to prevent rain, spray, or dust gaining access to the internal parts of the instrument.

Sunshades are provided to fit over the windows, as shown in fig. 6, to afford some protection against rain or spray settling upon the windows, and to exclude direct sunlight:

The details of the instrument are made as far as possible on the interchangeable system, so that if any parts are lost or mislaid they can be readily replaced.

ACCESSORIES.

The range finder is supplied in a strong teak-wood box, and it is held in the box by rubber pads and leather straps, to prevent the instrument receiving damage while out of use, and especially during carriage.

Spare electric lamps, cloths for cleaning the windows, and othe accessories are provided.

A waterproof cover is supplied, which can be thrown over the instrument when it is desired to leave it in position, but not in use, for some time; but the instrument is designed so as to be capable of standing exposure in all ordinary weather.

Detailed instructions for using the range finder and its mountings are supplied with each instrument.

ACCURACY.

The range finder above described is of 4 feet 6 inches (1.37 meters) base, and is recommended for use in connection with guns on warships of all kinds, forts, shore batteries, etc.; also for submarine mining operations, and for navigation.

The table of test readings given at the end of the description will serve to indicate the accuracy obtainable under good atmospheric and other conditions.

These readings were taken in the ordinary course of testing and adjusting instruments before delivery.

It will be observed that the readings given in yards were made with instruments of consecutive numbers; they were not made with any view to publication, and they are not selected as being unusually good.

If for any special service greater accuracy is desired at very long ranges than can be obtained with a base of 4 feet 6 inches, instruments with longer base can be made to order; and for use on torpedo boats or other small craft a range finder of 3 feet base can be supplied.

The 3-foot-base range finder is also supplied for use with field artillery, and for that purpose is made largely of aluminum and weighs only 15 pounds (about 7 kilograms).

NAVAL MOUNTING.

(See Plates II and III.)

For use at sea the range finder is mounted as illustrated in Plates II and III.

It will be seen that the instrument is supported in bearings (fig. 14) attached to a swinging frame.

The frame carries a balance weight inside the tank and swings upon knife edges, which knife edges are carried upon the end plates of the tank.

A handle is fixed to the swinging frame. This handle is held by the finger and thumb of the observer's left hand, and thus the motions of the swinging weight are kept under control.

The tank (which may be partly filled with water to help steady the swinging weight, though this is not found necessary) is supported upon a vertical spindle projecting upward from the teak-wood pedestal (fig. 14).

The instrument is moved in azimuth by rotation of the tank upon the pedestal spindle.

The instrument is directed correctly in altitude by rotating it in the bearings by means of the worm (fig. 14), the handle being left free. The swinging weight will then tend to keep it so directed; but complete steadiness of the instrument can only be obtained by the observer controlling the motions by means of the handle.

Bolts are provided for locking the swinging weight and tank when not in use.

From the nature of the observation to be made it will be seen that it is not necessary that the instrument should be mounted on gimbals. Motions in the vertical plane in which the length of the instrument lies merely make the object appear inclined as regards the "separating line." As these motions are never likely to exceed 30 degrees each way, and will seldom exceed 10 degrees, no difficulty is experienced in consequence of such motion.

When erected on the naval mounting the eyepieces of the range finder are at a height of about 5 feet (1.5 meters) from the deck. The observer presses his face firmly into the rubber face piece, and his eyes are thus guided to the eyepiece apertures. The fingers of the right hand are placed upon the working head, while the handle is lightly held by the finger and thumb of the left hand. The remaining fingers of the left hand may be allowed to slide along the under side of the tank to give increased steadiness.

The body is pressed against the tank to assist the hands in keeping the instrument correctly directed in azimuth.

The instrument is thus completely under control, and an object can with ease be kept constantly in the field of view.

After a few days' practice it will be found much easier to keep an object in the field of view of the range finder than in the field of an ordinary telescope. It has been proved by trial on board ship that the range finder can be used successfully in such a sea as would render practice with large guns impossible.

POSITIONS FOR NAVAL RANGE FINDER.

The range finder and naval mounting are constructed of non-magnetic materials, so that they may be placed, if desired, in close proximity to the standard compass.

It is impossible on board ship to command the entire horizon from one station, owing to the intervention of funnels, masts, etc. Two instruments are necessary and sufficient if suitably placed. The top of the chart house is usually chosen as the best position for the forward range finder, and the after bridge for the aft range finder; the ends of the bridges are also suitable stations.

The disposition of the instruments on any ship must necessarily depend on the arrangement of her armament, masts, etc.; but it is advisable to select positions in which there is little vibration, since steadiness of the range finder conduces to more accurate observation.

TRANSMITTING AND RECEIVING INSTRUMENTS.

Instruments for transmitting ranges from the range finder to the conning tower, and for transmitting ranges and orders from the conning tower to the gun stations have also been supplied to vessels.

USE IN MANŒUVRES, NAVIGATION, ETC.

An instrument that can measure the distance of any object in a few seconds, by night as well as by day, must commend itself to officers engaged in manœuvring. No data respecting individual ships are required, as is the case with "station keepers" or sextants when used for range finding, and the observer is able to tell almost at a glance the distance of any vessel in the fleet.

The range finder will also be found useful in carrying out tests of the manœuvring qualities of individual ships without interfering with the customary exercises and tactics. For example, the turning circle of a ship under any given circumstances can be worked out by causing the ship to steam around or near a floating object—such as another ship or a small boat or target carrying an upright pole—determining the distance and bearing of the object simultaneously at given intervals of time and plotting the data thus obtained.

Again, the speed of a vessel can be determined by causing it to steam past a stationary vessel or small boat and noting the instant when the object is, say, 1,000 yards ahead, and again when it is 1,000 yards astern. The speed of a vessel can be ascertained in this way with quite sufficient accuracy for all ordinary purposes, and, indeed, well within the variations of speed that result under nominally identical circumstances from unknown causes, say within 1 per cent. And as this does not necessitate the taking of the vessel to a measured mile it can be carried out as frequently and under as great a variety of circumstances as may be

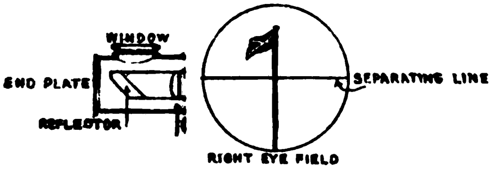


Fig. 8.

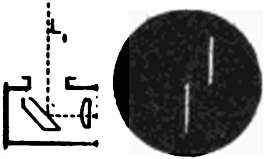


Fig. 10.

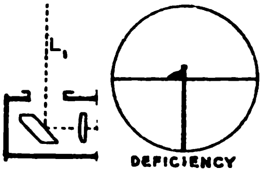
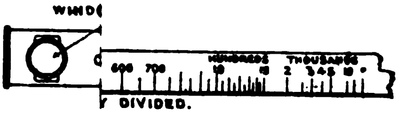
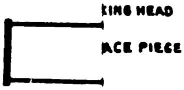


Fig. 12.





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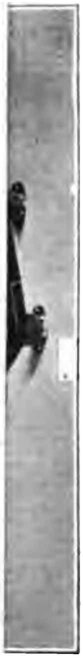

Fig. 17.

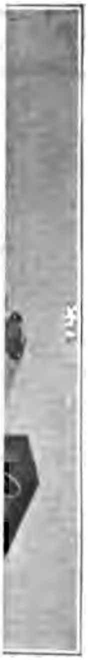

Fig. 16.

BARR AND STROUD RANGE FINDER—PLATE III. GENERAL VIEW OF NAVAL MOUNTING.

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THE BARR AND STROUD RANGE FINDER

PLATE II

DETAILS OF NAVAL MOUNTING

LEFT BEARING

RIGHT BEARING

Fig. 16.

Fig. 17.

BARR AND STROUD RANGE FINDER—PLATE III. GENERAL VIEW OF NAVAL MOUNTING.

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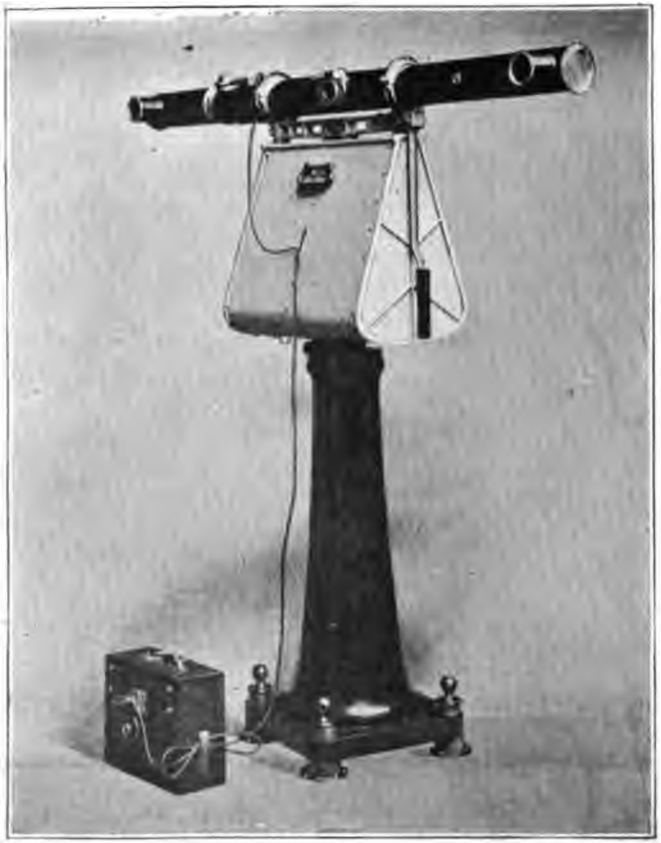

Fig. 16.

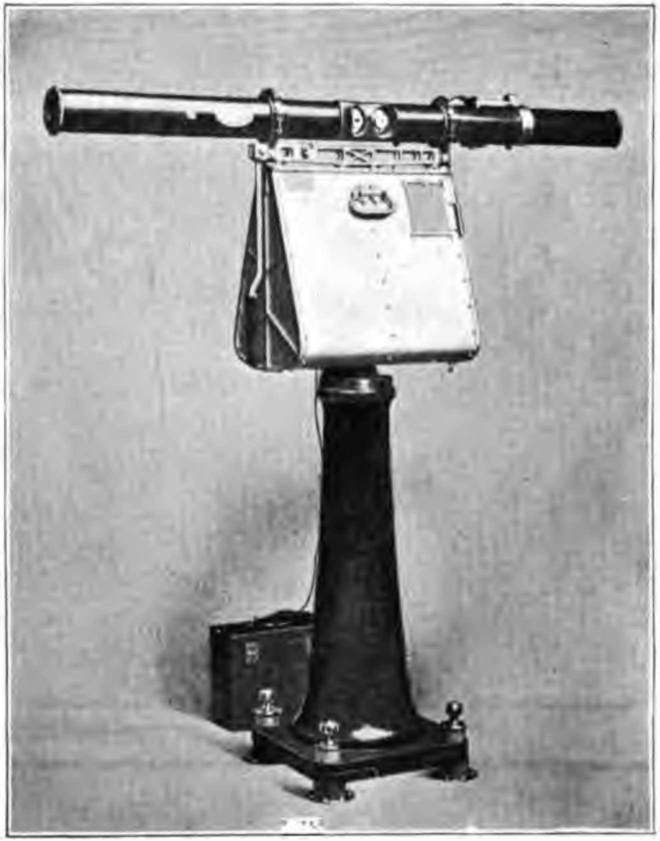

Fig. 17.

BARR AND STROUD RANGE FINDER—PLATE III. GENERAL VIEW OF NAVAL MOUNTING.

desired. It will be evident also that as the vessel and the floating object partake alike of the motion due to any general current the effect of such current is eliminated.

The range finder is of great service as an aid to navigation. It is very well known that the distance of any object at sea, and more especially the distance of a light, can not be estimated with any approach to accuracy. So much is this the case that in certain weathers experienced navigators frequently mistake a distant light-house for a near ship's light and vice versa. The method sometimes adopted for determining the distance of an object on shore by observing the change of bearing upon a known distance run, is, of course, not applicable at all when the light is within some points of the bow (the most important case), and in any case it requires a considerable amount of time and may involve the incurring of great danger. The range finder will determine the distance of a light in a few seconds, and the light can, when necessary, be kept constantly in view and the distance read as frequently as desired.

For such work as taking a point of departure, coming to anchor (more especially in a strange port), etc., the instrument effects a great saving in time and trouble over any other means in general use. The distance from any given landmark is determined by a single observation, and if the bearing of the mark be taken at the same time the position of the ship relatively to the mark observed can be completely ascertained at once and without any calculation.

The astigmatiser has been found to render the instrument very serviceable in determining the distance of a torpedo boat or other object under the action of a searchlight. The search light illuminates some parts of the object more strongly than others, so that these appear as bright points and patches, and the astigmatiser draws each of these out into a clearly defined vertical line or streak of light, thus causing the object to appear as a comb of bright lines, which can be worked upon with great ease.

It need hardly be pointed out that a trustworthy range finder is invaluable in the training of seamen and gunners in judging distances at sea under all varieties of circumstances.

The value of the instrument for nautical surveying will be obvious.

Many other applications of the instrument will present themselves to those acquainted with maritime affairs

Readings taken on shore.

Instrument No.	Graduated in—	Range of a house distant 326 yards or 298 meters.	Equivalent error at 3,000 yards.[1]	Range of a chimney distant 1,975 yards or 1,805 meters.	Equivalent error at 3,000 yards.[1]	Range of a steeple distant 5,950 yards or 5,440 meters.	Equivalent error at 3,000 yards.[1]
		Yards.	*Per cent.*	*Yards.*	*Per cent.*	*Yards.*	*Per cent.*
68	Yards	325.9	−0.28	1,975	0.00	6,000	+0.42
		5.8	− .56	1,985	+ .77	6,000	+ .42
		6.0	.00	1,970	− .38	5,950	.00
		5.8	− .56	1,970	− .38	5,900	− .42
		5.9	− .28	1,970	− .38	5,900	− .42
	Mean	325.88	− .34	1,974	− .08	5,950	.00
69	Yards	325.7	− .85	1,970	− .38	6,000	+ .42
		5.7	− .85	1,980	+ .38	6,000	+ .42
		5.6	−1.13	1,960	−1.15	5,950	.00
		5.8	− .56	1,980	+ .38	6,050	+ .84
		5.6	−1.13	1,960	−1.15	5,950	.00
	Mean	325.68	− .90	1,970	− .38	5,990	+ .34
70	Yards	326.3	+ .85	1,990	+1.15	6,050	+ .84
		6.0	.00	1,970	− .38	5,950	.00
		6.3	+ .85	1,990	+1.15	5,950	.00
		6.0	.00	1,990	+1.15	5,950	.00
		6.2	+ .56	1,970	− .38	6,000	+ .42
	Mean	326.16	+ .45	1,982	+ .54	5,980	+ .25
71	Yards	326.0	.00	1,975	.00	6,000	+ .42
		6.0	.00	1,975	.00	5,950	.00
		6.0	.00	1,985	+ .77	6,000	+ .42
		6.1	+ .28	1,965	− .77	6,000	+ .42
		6.3	+ .85	1,975	.00	5,950	.00
	Mean	326.08	+ .23	1,975	.00	5,980	+ .25
		Meters.	*Per cent.*	*Meters.*	*Per cent.*	*Meters.*	*Per cent.*
81	Meters	298.3	+1.02	1,805	.00	5,500	+ .61
		8.1	+ .34	1,810	+ .46	5,450	+ .10
		8.2	+ .68	1,795	− .92	5,450	+ .10
		8.3	+1.02	1,800	− .46	5,450	+ .10
		8.2	+ .68	1,805	.00	5,450	+ .10
	Mean	298.22	+ .75	1,803	− .18	5,460	+ .20

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[1] The accuracy asked for by the British Admiralty in their advertisement for range finders for the navy was 3 per cent at 3,000 yards. The equivalent error at 3,000 meters is approximately the same as that at 3,000 yards.

THE ZEISS STEREOSCOPIC RANGE FINDER.

Figure 1, portable type.

The working of this range finder may be illustrated by placing the annexed stereoscopic picture (fig. 2) in an ordinary stereoscope. The effect of depth thus obtained is identical with that of a range finder of 13-fold magnifying power and an effective base of 78 centimeters. Total depth in perspective $=$ magnifying power $\times \dfrac{\text{base}}{\text{distance between the eyes}} = 156.$

When looking through the range finder a stereoscopic view of the field of vision appears to be actually brought into the instrument, and the points in the measuring scale appear, in perspective, to be actually over the various objects in the picture presented.

The measuring scale floating over the landscape (a view near Jena and the valley of the Saale) consists of three straight rows of marks for measuring depth in perspective. The first row, above the foreground of the landscape, measures distances from 450 to 1,000 meters; the second, across the valley between the villa on the right and the crest of the hill, distances from 1,000 to 2,000 meters; and the third, distances from 2,000 to 10,000 meters.

To give increased effect to the impression of depth in perspective, the screens restrict the field of view so that their openings seem to be actual objects, just as if they were holes in a wall through which the landscape is being examined.

The measuring of the distance of any particular object in the landscape is done in the annexed stereoscopic picture (fig. 2), as well as in the range finder itself, by noting what point in the row of marks the highest point of such object comes to occupy. In this manner the respective distances of a number of objects in the stereoscopic picture can be read off without difficulty. The distances of objects which, like the villa on the right, reach with their highest points close to the measuring scale, are the easiest to measure. As to the range of hills visible in the distance the result is not satisfactory, owing partly to the comparatively great distances of the marks from the landscape and partly to the imperfectness of the picture at this place.

The Zeiss stereoscopic range finder is made in three sizes, of 50, 87, and 144 centimeter base, respectively. The scale of the first model comprises distances from 75 to 3,000 meters, that of the second from 300 to 5,000 meters, and that of the third from 700 to 10,000 meters. The telescopic magnifying power of the three models is 8, 14, and 23 fold, respectively. The smallest model, which weighs only 3 kilograms, can be easily carried and held in the hand without the use of a stand. The two larger models, weighing 8 and 13.5 kilograms, respectively, require stands.

The theory of this instrument takes advantage of man's ability to see stereoscopically, and also utilizes the telescope to extend the power of what Helmholtz called the telestereoscope.

The range finder consists of two rigidly connected telescopes. The adjustment for the distance between observers' eyes is made by an apparatus, independent of the telescope proper, for changing the distance between the two eyepieces. Because of this arrangement it is impossible to change the inclination of the optical axes of the telescopes. To prevent flexure of the telescopes from changes in temperature (wind, sunshine, handling, etc.), and to protect them from external injury from shocks, etc., they are inclosed in cylinders secured to the centerpiece, without contact with the telescopes proper, and covered on the outside with leather and at the ends with felt cushions. External changes of temperature are thereby transmitted evenly to the interior parts, so that even under the most unfavorable atmospheric conditions no error will occur in the adjustment of the instrument.

Precautions had also to be taken to prevent the flexure of the telescopes by their own weight. It has been found that in instruments having bases not exceeding 50 centimeters this source of error can be prevented from interfering with accurate measurement by the selection of proper material and suitable diameter of tubes. For these smaller instruments, therefore, the special adjusting device invented by Professor Abbe, which is used for the larger models, can be entirely dispensed with.

But even for the smaller instruments, means have been devised which enable the observer to adjust, without going to the workshop, any displacements in the relative positions of the stereoscopic picture and the scale, such as may result from external concussions and shocks. For this purpose the two scales in all the instruments are fixed on slides that can be adjusted from the outside, the one in a vertical, the other in a horizontal direction, so that it is possible to correct a displacement of the picture by adjusting the scales.

Finally, the range finder is fitted with accessory devices which enable the apparatus to be used also for observation at night and by twilight for measuring the distance of lights. The accessory devices for this purpose consist of two white screens perforated in the middle, which are secured in front of the telescopic objectives at an angle of 45 degrees, and illuminated from a source of light placed in front of the center of the apparatus. In the field of view, thus evenly illuminated, the light to be measured appears as a material object floating in the air, and as such it can be measured by means of the stereoscopic scale of depths like any other object.

The position of the marks is calculated as follows: In figure 3, O_1 and O_2 are the objectives of the binocular telescope; S_1 and S_2 are the focal planes, and *Oc.* is the eyepiece. The Porro system of prisms, which places the view in an upright position and effects the reduction of the distance between the axes of the telescopes to the distance A between the eyes, is indicated by U, S. The effective base—that is to say, the distance between the objective lenses—is indicated by B. When the telescopes are exactly parallel, the images M and M′ of an object at an infinite distance will be placed exactly alike in each field of view; but this will not be the case when an object is at a finite distance, E. If we assume that the point in the plane S_1 coincides with M, it will at once be seen that the point M′ of the same object in the plane S_2 suffers a parallactic displacement (*a*) from M′ to M″, which at the given distance is computed at

$$a = \frac{B\,F}{E}.$$

Moreover, the marks are arranged in two or three rows extending into the depth at different inclinations. The relative size of the series of marks of one and the same row is adapted as far as practicable to the rules of perspective. Allowance has also been made as far as possible for the natural conditions of the landscape views by a slight upward rise of the different rows of marks as the distance increases.

The measuring proper consists simply in holding the instrument so that the row of marks appears to float free in the air above the object to be measured, and it is only necessary to note under which one of the marks the object in question is located. If the object appears between two marks, the fraction of the interval is estimated.

The accuracy of measurement aimed at for a certain distance depends not only on the limits which the keenness of human eyesight sets to stereoscopic observation of depth ($\delta = 30$ seconds), but also on the following two optical constants of the binocular telescope: First, the distance between the objectives, B, and second, the magnifying power of the telescope, V. When these are given, the errors in measurement due to individual instruments and to distances may be computed without difficulty as

$$dE = -\frac{E^2}{B\,F}da = -\frac{E^2}{B.V}\delta.$$

For the numerical computation of dE we may say more simply:

$$dE = \frac{E^2}{R},$$

in which R has the following value:

$$R = r \times \frac{B}{A}V.$$

The factor $\frac{B}{A}V$ gives the stereoscopic effect in perspective attained by the binocular telescope. The numerical values for such stereoscopic effect—unaided eye effect being taken as unity—for the three models of range finders referred to are, respectively, 63, 188 and 510. The other factor, *r*, is the distance of the stereoscopic definition by the unaided eye; in other words, the distance at which an object is seen at an angle of convergence of the eyes of 0.5 minute, therefore just separated from points up to infinity beyond it. For the average distance between the eyes, A = 65 millimeters, the value *r* ($r = A/\delta$) is equal to 447 meters. Hence, the distance R of stereoscopic definition as increased by the optical power of the instrument is for the three models referred to 28 kilometers, 84 kilometers and 228 kilometers, respectively.

In consequence the probability of error is as shown in the following table:

Distance.	First model, 8-fold magnifying power; base, 50 cm.	Second model, 14-fold magnifying power; base, 87 cm.	Third model, 23-fold magnifying power; base, 144 cm.
	Meters.	*Meters.*	*Meters.*
500 meters	9	3	....
1,000 meters	35	12	5
2,000 meters	141	50	18
4,000 meters	564	200	70
8,000 meters	....	800	280

Of course, the above figures apply only to errors in perfectly transparent and calm air. As the atmosphere becomes hazy or disturbed, the errors increase more rapidly with increasing distance than is given in the table.

For the smaller instrument, which is used without a stand, the amount of error can easily be ascertained by approaching or receding from the object until some mark appears directly over it, and repeating this observation several times independently; the distance between the extreme points so fixed will give the extreme error for the particular range.

In an article published in No. 66 of the *Militär - Wochenblatt* of 1899, explanative of the Zeiss range finder, the writer gives it as his opinion that this instrument is in every way suitable for military purposes. For persons with approximately normal eyesight half an hour is sufficient in order to become acquainted with the practical working of the instrument, but two or three days' practice are required to fit them for taking accurate observations.

The advantages claimed for this range finder over those hitherto in use are as follows:

1. It is used like any other binocular telescope; consequently the observer can take ranges from the firing line, and in any position—standing, kneeling, or even lying down—and need not attract the attention of the enemy any more than a scout or a man in the ranks.

2. The instrument is used and carried by one man, and he requires no assistant.

3. The distance to be determined is measured from a single point, the eyes directed on the object itself and not at a point on one side, often difficult to find (Souchier), or even at a reflecting apparatus placed laterally (Bickel).

4. The observer reads the range through the glass and without removing the eyes from the eyepieces. In fact, the Zeiss range finder is a remarkably good reconnoissance glass as well.

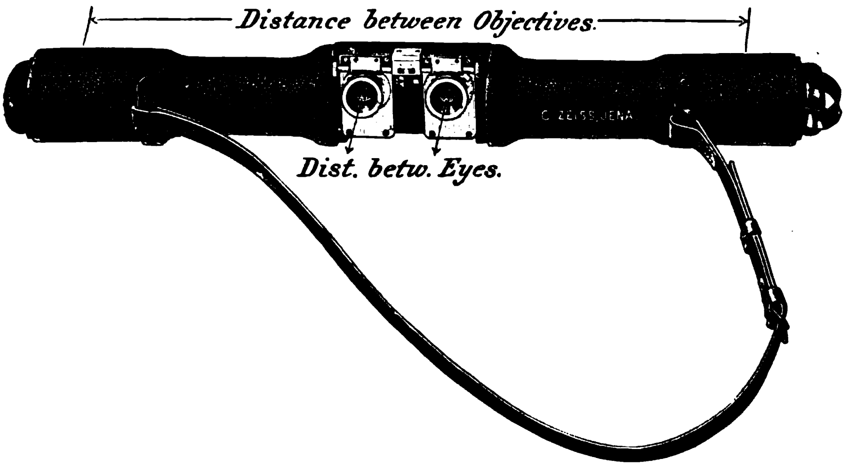


Fig. 1.—ZEISS STEREOSCOPIC RANGE FINDER.

Magnifying power eight times. One fifth actual size.

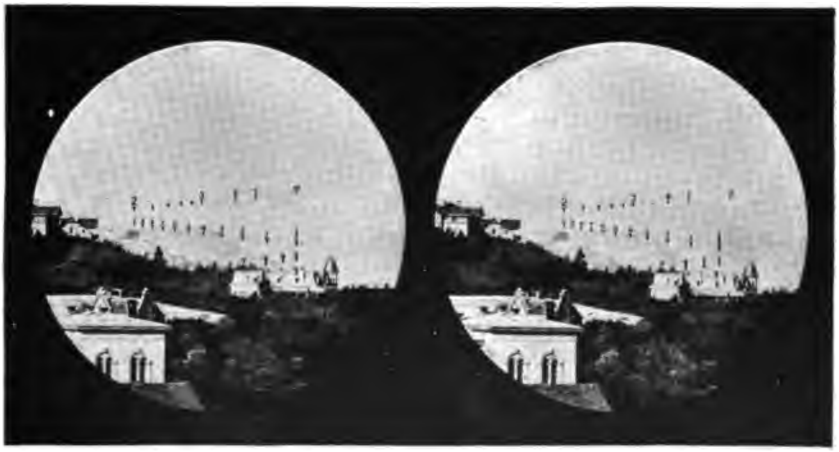
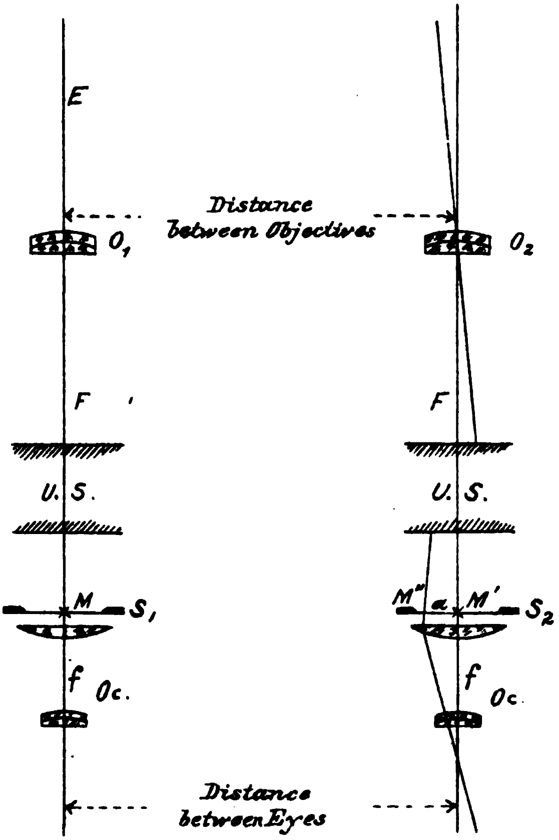


Fig. 2.

Fig. III.



ZEISS STEREOSCOPIC RANGE FINDER.

5. Since both eyes are used at the same time, there is less danger of tired vision, blinking and straining of the eyes.

6. One particular advantage of this stereoscopic range finder consists in the fact that the accuracy of the distances measured is unaffected by the nature and appearance of the objects on which the ranges are taken. Objects which have no marked points, such as distant folds of the ground, irregular thickets, the fringe of a wood, and such others as have not even contours, such as clouds of smoke or dust, are as easy to range upon stereoscopically as a church tower, provided they stand out from the background when seen through the binocular.

7. The effects of good or bad light and greater or less transparency of the atmosphere are less felt because of the localization of the object with both eyes.

8. Ranging on moving objects—as, for instance, birds flying or balloons—is not only practicable, but is much easier on account of their ready isolation from their surroundings for stereoscopic measurements.

9. Lastly, by a simple arrangement the stereoscopic scale can be made visible by twilight or at night, so that it is possible to take the range of a distant point of light, such as a lantern, a lamp-lit window, or a bivouac fire. This special point of the Zeiss range finder should recommend it to naval men in particular.

ARMOR.

The object of this paper is not to discuss the cost or the methods of manufacture of armor, but to give the results of actual armor tests, and thus indirectly explain the contract requirements of various nations.

The armor trials that have taken place have still further established the superiority of the Krupp process. Firing trials have shown that it offers from 20 to 30 per cent more resistance to the attack of armor-piercing shell than harveyized armor, and in consequence it has been adopted by England, Germany, France, Russia, Japan, and several of the smaller powers.

Certain features of the Krupp process are secret, and the secret is well kept, though in many hands. According to Captain Orde-Browne, the process "consists mainly in the use of chromium to such an extent that great brittleness and hardness might be expected. Sudden cooling is carried out in such a way as might be expected to ruin the metal, but the result is great toughness. It must be understood, however, that nickel is also used, and nickel has long been known to give toughness in a remarkable degree." English, American, and French armor makers have acquired the right from Krupp to use his process, paying a large sum for the same, and in addition a royalty of from $40 to $50 on every ton manufactured. In connection with a comparison of Krupp armor made by different firms, the Captain says that it "is no doubt subject to variation, and since it has been adopted in this country (England) each maker has improved and modified it." It is a notable fact that plates made by this process by Brown & Co., of England, and also the Carnegie Company, have shown a better figure of merit than is credited to those made by Krupp.

The great increase in the resisting power of Krupp armor has made it possible to obtain the same protection by a reduced thickness of metal; and, in consequence, if the total weight allowed for armor in a vessel of given tonnage remains the same, the protection can be spread over a much greater area without an increase in her displacement.

As it is for obvious reasons more important to know the resisting power of the armor that is being carried by foreign battleships than the place of its manufacture, the following data concerning recent firing trials are given under the name of the country owning the vessels, rather than that of the kind of armor or maker. As far as practicable the contract requirements, including the manner in which the plates were set up, and the formulæ regulating the striking velocities are given.

THE NETHERLANDS.

The following are the details of the test of an armor plate intended for H. M. battleship *Koningin Regentes*.

The nickel-steel plate, 3.3 meters long, 2.2 meters wide, and 15 centimeters thick, manufactured by the firm of Krupp after its own process, was, under the contract, to be subjected to a test with a 15-centimeter gun. The Krupp armor-piercing projectiles to be used at the trial, weighing about 45.5 kilograms each, were to be furnished by the Dutch navy.

The contract further contained the following conditions:

The shots are to be fired normally against the plates.

The striking velocity is to be regulated according to the formula:

$$\mathrm{v}=\mathrm{c}\times 1530\times\frac{a\,0.75}{p\,0.5}\times e\,0.7$$

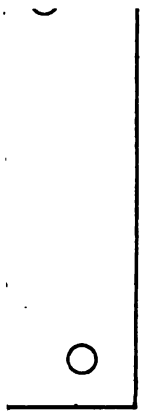
in which

v=striking velocity in meters,
a=caliber of gun in decimeters,
p=weight of projectile in kilograms,
e=thickness of armor plate in decimeters,
c=coefficient.

This coefficient c for a 15-centimeter plate is to be 1.38.

Three shots are to be fired, which, measured from center to center, are to be 55 centimeters from each other, and the distance of a shot from the edge of the plate shall not be less than 55 centimeters.

None of these shots shall perforate the plate, nor shall any through cracks occur.



ETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

The plate shall then be fired upon with greater velocity so that perforation will take place; this is for the purpose of ascertaining whether the plate will crack when perforated.

The plate will be considered perforated when the rear end of the projectile penetrates to the back of the armor plate.

The plate was secured by twelve 65-millimeter nickel-steel bolts to a 60-centimeter (2 by 30 centimeter) oak backing, set up against an iron structure with 40-centimeter (2 by 20 centimeter) skin.

When it had been demonstrated by rounds I to IV that the contract conditions were fulfilled, four more rounds were fired in order to further determine the qualities of the plate, the sixth round being fired at one of the corners at a short distance from the edges, namely, 27 and 33 centimeters, respectively. For rounds V to VIII (inclusive) capped steel shells were used.

The effect of each shot is given in the table, and is illustrated by the annexed plate.

Place and date of trial.	Angle of incidence.	Number of shot.	Weight of projectile in kg.	Striking velocity in m. s.	Energy in m. t.			Effect of shot.		Distance from center to center of shot in mm.
					Total.	Per cm. of circumference.	Per cm.^{2} of area.	On plate.	On projectile.	
	Degrees.									
Meppen, Nov. 17, 1899.	87	I.	44.75	581.6	771.5	16.47	4.419	Not perforated; no cracks. The face of the plate was indented 5 to 10 mm. by the crushed head of the projectile, over a diameter of 24 cm. From the hard face around the point of impact pieces 30 mm. thick and from 50 to 100 mm. wide were scaled off. The back of the plate showed a bulge 20 mm. high and 35 cm. diameter.	Crushed	
Do.	87	II.	44.65	579.1	763.2	16.29	4.371	Not perforated; no cracks. Same as at round I, while at rounds following further flakes were scaled off the face of the plate.	do	Between I and II, 490.
Do.	87	III.	44.90	575.1	756.9	16.17	4.335	Not perforated; no cracks. Same as at II.	do	Between I and III, 590; between II and III, 635.
Do.	87	IV.	44.80	675.3	1041	22.23	5.991	Perforated; no cracks. The piece of the plate forced out, together with the head of the projectile remaining in it, penetrated to a depth of 15 cm. into the first layer of the backing. From the hard face of the plate around point of impact pieces 10 to 50 mm. thick and 50 to 250 mm. wide were scaled off.	do	Between III and IV, 600; between II and IV, 530.
Do.	87	V.	41	708.2	1048	22.38	6.008	Perforated; no cracks. The projectile pierced the plate, the 60 cm. oak backing, and the 40 mm. inner skin, striking along one of the struts and splintering a beam lying back of it.	Broken in 2 pieces.	Between IV and V, 1220.

							The projectile broke, and the two pieces were found, respectively, 400 and 600 m. back of the earth butt. From the hard face pieces 20 mm. thick and 50 to 150 mm. wide were scaled off. From shot I to shots II and III a fine crack developed on the face of the plate.		
Do.........	87	VI.	44.60	680.6	1058	22.48	6.081	Not perforated .... From the edge of the plate, to the right and above the point of impact, a piece was scaled off and forced 70 mm. back; this piece was still connected with the plate. Two cracks 60 to 70 mm. deep developed at the lower edge of the plate.	Broken into small fragments.	Between V and VI, 950.
Do.........	87	VII.	44.70	655.3	978.3	20.89	5.608	Perforated; no cracks .... The head of the projectile penetrated the plate. The piece forced out, weighing 24 kg., together with the head of the projectile, entered to a depth of 10 cm. into the first layer of the backing. From the hard face pieces 10 to 30 mm. thick and 50 to 150 mm. wide were scaled off.	Crushed	Between IV and VII, 680; between V and VII, 550.
Do.........	87	VIII.	41.15	690.8	1001	21.37	5.782	Perforated; no cracks............................ The projectile perforated the plate, the backing, and skin. The two pieces of the projectile were found, respectively, 30 and 500 m. back of the earth butt (the head 30 m.). From the hard face pieces 10 to 30 mm. thick and 20 to 80 mm. wide were scaled off.	Broken in 2 pieces.	Between V and VIII, 800.

JAPAN.

TEST OF PLATE SELECTED FROM THE LOT PREPARED FOR H. I. J. M. BATTLESHIP YAKUMO.

Immediately after the war with China the Japanese Government devoted itself to the building of a powerful navy. In 1895 the laying down of five large armor-clads was undertaken, and all these vessels have since been launched. Six cruisers of 9,700 tons are now building. Among these is the *Yakumo*, which was launched July 8, 1899, at the Vulcan Works, at Stettin. The maximum thickness of her armor belt, which surrounds the entire line of flotation, is 178 millimeters; at the extremities it decreases to 88 millimeters. For protection against damage by rapid-fire guns, and especially by powerful explosive shells in the vicinity of the line of flotation, this ship carries above the principal armor belt, over a length of 61 meters, a second armor 127 millimeters thick, the extremities of which are joined by bulkheads in such manner as to form a closed redoubt which at the same time protects the lower part of the large fore and aft turrets of the cruiser.

The total weight of the armor, which was manufactured at the Krupp works, at Essen, may be estimated at 2,100 tons. A plate taken from the lot prepared for the *Yakumo* by the Japanese committee on acceptance was subjected to firing trials on the proving grounds at Meppen, August 19, 1898. This plate, 3.80 meters long, 2.14 meters high, and 178 millimeters thick, weighed about 11,300 kilograms. It was fixed upon an oak backing 60 centimeters thick, and received three 17-centimeter projectiles. The results are given in the table.

From the second lot for the *Yakumo* the committee chose a plate 3.78 meters long, 2.41 meters high, and 114 millimeters thick, weighing about 8,100 kilograms. The firing trials with this plate, which was set up in the same manner as the preceding one, took place November 21, 1898.

As is seen from the table and the annexed illustrations, both the plates stood the test admirably, and their qualities entirely confirmed the experiments thus far made with plates treated according to the Krupp process. They did not show the least trace of cracks either on the face or at the back.

It is important to note that neither of the two plates was tested to its limit of resistance. The projectile fired with the greatest energy against the 114-millimeter plate would have entirely pierced a 207-millimeter plate of ordinary steel;[1] that is to say, 1.8 times as thick as the plate tested, upon which it only produced a boss 48 millimeters high, without cracks, on the back of the plate.

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[1] According to the formula of Jac. de Marre.

For the sake of comparison it may be of interest to add a few results of firing trials with a plate which also came from the Krupp works, but which was struck with projectiles of a caliber greatly superior to its thickness.

As in the case of the Japanese plates cited above, this was taken from a lot of plates by the representative of the navy for whom the consignment was intended. The firing trials took place on April 11, 1899, at Meppen. The plate was 2.98 meters long, 2.10 meters high, and 115 millimeters thick; it weighed 5,730 kilograms, and was attached to a wood backing of oak 2 by 30 centimeters by means of 10 bolts, and placed against an iron support.

At the first shot the steel 10.5-centimeter bursting shell, weighing 16 kilograms, struck the plate at a velocity of 722.3 meters; the projectile was shattered, the head remaining fast in the plate in such manner that the depth of penetration could not be measured. The back of the plate showed a boss 35 millimeters high, without cracks. The kinetic energy of the projectile would have sufficed to entirely pierce a plate of ordinary steel 235 millimeters thick, which, divided by the thickness of the trial plate, gives the quotient 2.05.

The plate was next struck by three projectiles of 15 centimeters; that is, having calibers greater than the thickness of the plate. The projectiles weighed 51 kilograms, and struck the plate at velocities of 442.5, 462.4, and 487.2 meters, respectively. The kinetic energy of the last shot would have sufficed to entirely pierce an ordinary steel plate 211 millimeters thick; that is to say, 1.83 times as thick as the trial plate, which only showed a boss 80 millimeters high, slightly cracked at the summit.

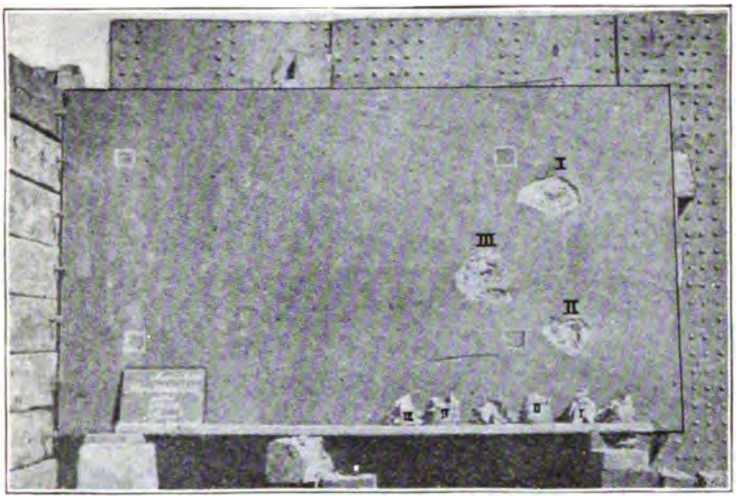
Hence the plate resisted projectiles having a caliber considerably greater than its thickness without being either pierced or cracked.

1. *Face-hardened nickel-steel Krupp plate 178 mm. thick. Length, 3.80 m.; height, 2.14 m.; weight, 11,300 kg. Date of trial, August 19, 1898.*

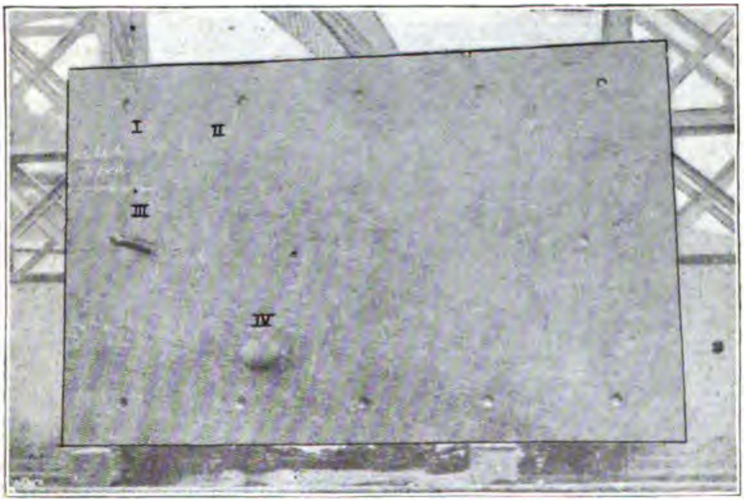
No. of shot.	Projectile.			Striking velocity.	Striking energy of projectile.			Angle of impact.	Thickness of ordinary steel plate which shot would have pierced	Thickness of test plate is to ordinary plate as 1:	Depth of penetration.	Effect of shot.	
	Caliber.	Kind.	Weight.		Total.	Per cm. of circumference.	Per sq. cm. of cross section.					On the projectile.	On the plate.
	Cm.		*Kg.*	*M.*	*M. t.*	*M. t.*	*M. t.*	*Degrees*	*Cm.*		*Cm.*		
1	17	Steel bursting shell L/3.5.	77.10	467.6	859.2	15.85	3.672	87	23.1	1.30	2.8	Shattered	Back bulge 8 mm. high, without cracks.
2	17	.....do	77.16	480.6	908.3	16.75	3.882	87	24.1	1.35	2.9	.....do	Back bulge 12 mm. high, without cracks.
3	17	.....do	77.52	479.6	908.8	16.76	3.884	87	24.1	1.35	2.7	.....do	Back bulge 10 mm. high, without cracks.

2. *Face-hardened nickel-steel Krupp plate 114 mm. thick. Length, 3.78 m.; height, 2.41 m.; weight, 8,100 kg. Date of trial, November 21, 1898.*

No. of shot.	Caliber.	Kind.	Weight.	Striking velocity.	Total.	Per cm. of circumference.	Per sq. cm. of cross section.	Angle of impact.	Thickness of ordinary steel plate which shot would have pierced	Thickness of test plate is to ordinary plate as 1:	Depth of penetration.	On the projectile.	On the plate.
1	10.5	Steel bursting shell L/3.1.	16.00	535.3	233.7	7.084	2.699	90	15.3	1.34	2.6	Shattered	A few superficial flakes detached from the face of the plate; at the back a bulge 15 mm. high, without cracks.
2	10.5	.....do	16.00	583.8	232.4	7.044	2.684	90	15.3	1.34	Not measured.	Shattered, the head remaining fast in the plate.	Back bulge 15 mm. high, without cracks.
3	10.5	.....do	16.00	584.3	232.8	7.058	2.689	90	15.3	1.34	3.0	Shattered	.....do
4	10.5	.....do	16.01	661.9	357.5	10.84	4.129	90	20.7	1.81	Not measured.	Shattered, the head remaining fast in the plate.	Back bulge 48 mm. high, without cracks.

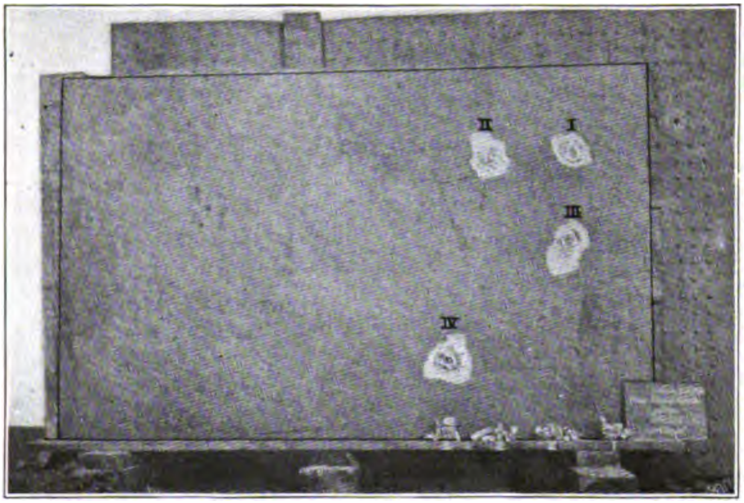


Face.

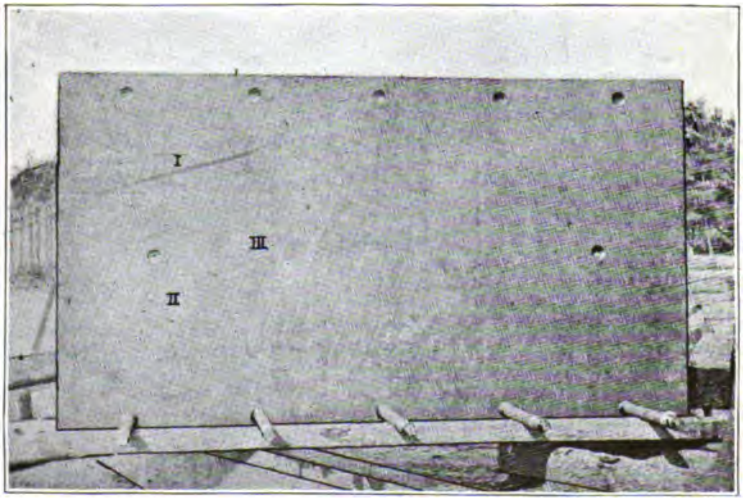


Back.

178 MM. FACE-HARDENED KRUPP PLATE, TESTED AUGUST 18, 1898.

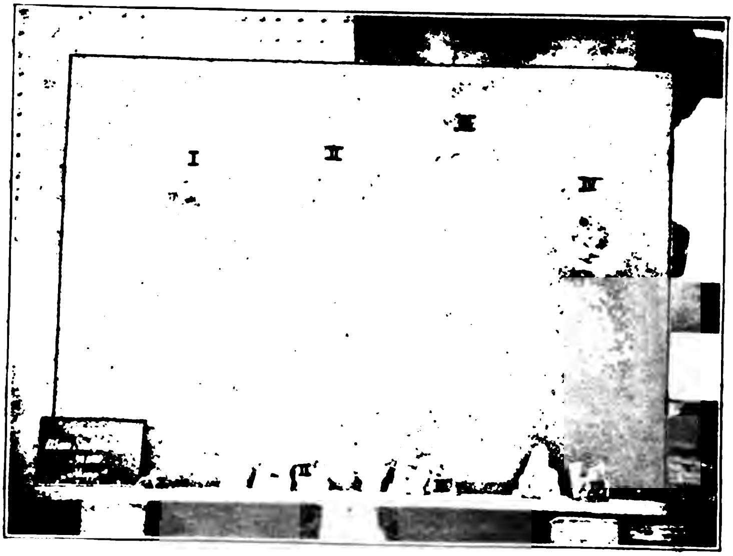


Face.

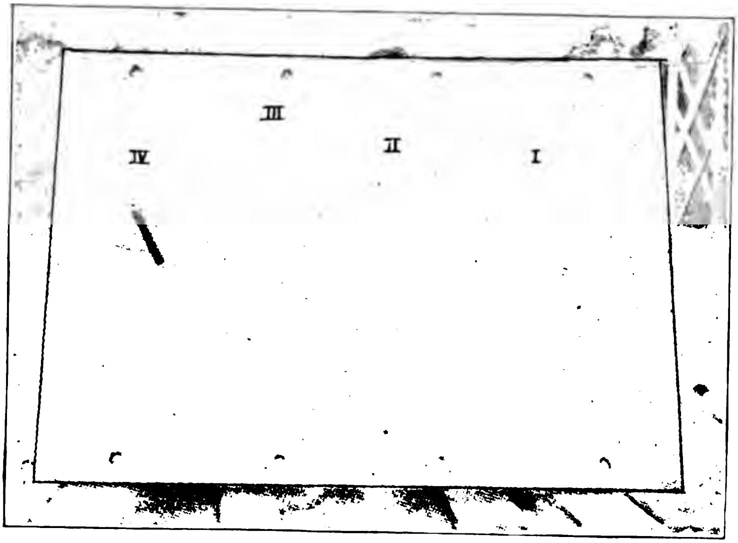


Back.

114 MM. FACE-HARDENED KRUPP PLATE, TESTED NOVEMBER 21, 1898.



Face.



Back.

115 MM. FACE-HARDENED KRUPP PLATE, TESTED APRIL 11, 1899.

3. *Face-hardened nickel-steel Krupp plate 115 mm. thick. Length, 2.98 m.; height, 2.10 m.; weight, 5,730 kg. Date of trial, April 11, 1899.*

1	10.5	Steel bursting shell L/3.1.	16.0	722.3	425.5	12.90	4.913	90	23.5	2.05	Not measured.	Shattered, the head remaining fast in the plate.	Back bulge 35 mm. high, without cracks.
2	15	Steel bursting shell L/3.4.	51.0	442.5	509.0	10.87	2.915	87	18.4	1.60	6.0	Shattered	Back bulge 45 mm. high, without cracks.
3	15	.....do	51.0	462.4	555.8	11.87	3.183	87	19.6	1.71	Not measured.	Shattered, the head remaining fast in the plate.	.....do
4	15	.....do	51.0	487.2	617.0	13.17	3.534	87	21.1	1.83	.....do	.....do	Back bulge 80 mm. high, cracked at the summit.

NORWAY.

Firing trial against a 6-inch armor plate furnished by the firm of John Brown, Atlas Works, Sheffield, selected from among those intended for the armor belts of the Norwegian battleships *Norge* and *Eidsvold:*

The armor trials took place November 10, 1899, at Armstrong's proving grounds at Ridsdale. The dimensions of the plate were 1.83 meters by 2.44 meters by 14.93 centimeters. It was set up about 70 meters from the muzzle of the gun and secured with eight 63.5-millimeter armor bolts to an oak backing about 6 centimeters thick in two layers. Behind the wooden backing was an inner skin made of 31-millimeter iron plate and secured to the backing with angle irons. The whole was supported in the rear by struts and a hard earth butt. The holes for the bolts were 73 millimeters deep.

The projectiles used at the trial were 15-centimeter shells of chrome steel, manufactured by Armstrong, Whitworth & Co. according to the Wheeler-Sterling method.

In accordance with the regulations of the British Admiralty the plate should be able to withstand four shots from a 6-inch gun with 100-pound projectiles, fired with a striking velocity of 1,960 foot-seconds, without producing perforations nor breaking the plate, and a fifth shot may be fired if deemed necessary. From the following table it will be seen that 6 projectiles were fired against the plate, the last 2 with 608.7 and 665.1 meters striking velocity, respectively.

The plate had before the firing some fine surface cracks, which after the third shot widened a little without, however, increasing in length or depth. No further cracks occurred at the front of the plate even after the fifth shot had been fired; but at the sixth shot a fine hair crack about 7.5 centimeters deep was formed between shots Nos. 4 and 5. At the back of the plate, where the projectiles caused bulges 3.8 to 6.4 centimeters high, some cracks were formed at the fourth shot extending from the top of the bulge, one of the cracks reaching to the edge of the plate, and at the sixth shot a very fine concentric crack appeared near the bottom of the bulge.

From the table it will be seen that the coefficient was greater than $\frac{41.02}{14.93} = 2.75$, since shot No. 6, which, according to the formula for penetration of wrought-iron plate, should have penetrated 41.02 centimeters, did not perforate the 14.93-centimeter plate.

Shot No. 4 appears to have exerted the greatest strain on the plate, inasmuch as there was the greatest penetration and the center of the back bulge was cracked. Shot No. 6 exerted less strain, although the striking velocity was considerably greater. This may be explained by the fact that at shot No. 4 the impact happened to be exactly normal, and it was for that reason easier for the point of the projectile to enter the plate. The cracks on the back of the plate show that the projectile almost reached the limit of penetration.

For a better understanding refer to the illustration.

$$\text{Figure of merit on Tresidder's system} = \frac{\text{Thickness of W. I. perforable}}{\text{Thickness of plate}} = \frac{16}{5.9} = 2.71.$$

$$\begin{array}{l}\text{Figure of merit on}\\ \quad\text{de Marre's system}\end{array} = \frac{\text{Striking velocity}}{\text{Velocity necessary to perforate ordinary steel}} = \frac{2{,}182}{1{,}340} = 1.628.$$

No. of shot.	Distance of shot from—				Weight of projectile.	Weight of charge.	Striking velocity.	Striking energy.	Penetration of wrought iron according to—		Actual penetration.	Height of back bulge.	Greatest diameter of bulge.	Remarks concerning plate.	Remarks concerning projectile.
	Right-hand edge.	Left-hand edge.	Upper edge.	Lower edge.					Krupp's formula.	Tresidder's formula.					
	Cm.	*Cm.*	*Cm.*	*Cm.*	*Kg.*	*Kg.*	*M.*	*M. t.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*		
1	69	....	68	....	46.5	5.497	579.7	796.4	33.42	33.42	6.7	3.5	abt. 0.36	To the right and below point of impact, a loose flake appeared which dropped off at the second shot.	Projectile broke into 3 large and about 20 smaller pieces; weight of largest piece, about 5 kg.
2	....	60	51	....	46.5	5.643	596.8	844.1	34.92	34.91	(1)	3.3	abt. .36	....	Projectile broke into 7 large and about 25 small pieces; weight of largest piece, 4 kg.
3	64	....	....	56	46.5	5.584	593.7	835.3	34.65	34.64	8.9	3.5	abt. .36	Surface cracks in plate were apparent	Projectile broke into 1 large piece (weight, 5.5 kg.) and 15 smaller pieces.
4	....	58	....	67	46.5	5.584	591.3	828.4	34.44	34.42	9.5	3.8	abt. .36	To the right and above point of impact appeared two surface cracks. The part of the plate between them flaked off at the sixth shot. From the top of the back bulge cracks extended, one of which reached to the left-hand edge of the plate. Depth of same could not be measured.	Projectile broke into 6 large and 15 small pieces; weight of largest piece, 4.8 kg.
5	....	43	....	117	46.5	5.84	608.7	878.2	35.96	35.96	6.4	3.8	abt. .36	....	Projectile broke into 4 large and 15 smaller pieces; weight of largest piece, 4.8 kg.
6	71	....	....	102	46.6	6.35	665.1	1050	41.80	40.75	(1)	6.4	abt. .36	Between points of impact of shots Nos. 4 and 5 appeared a fine hair crack about 7.5 cm. deep. At the bottom of the back bulge appeared a crack concentric with the former; it was so fine that its depth could not be measured.	Projectile broke into 1 large, 5 medium large, and about 10 small pieces; weight of largest piece, 15.3 kg.

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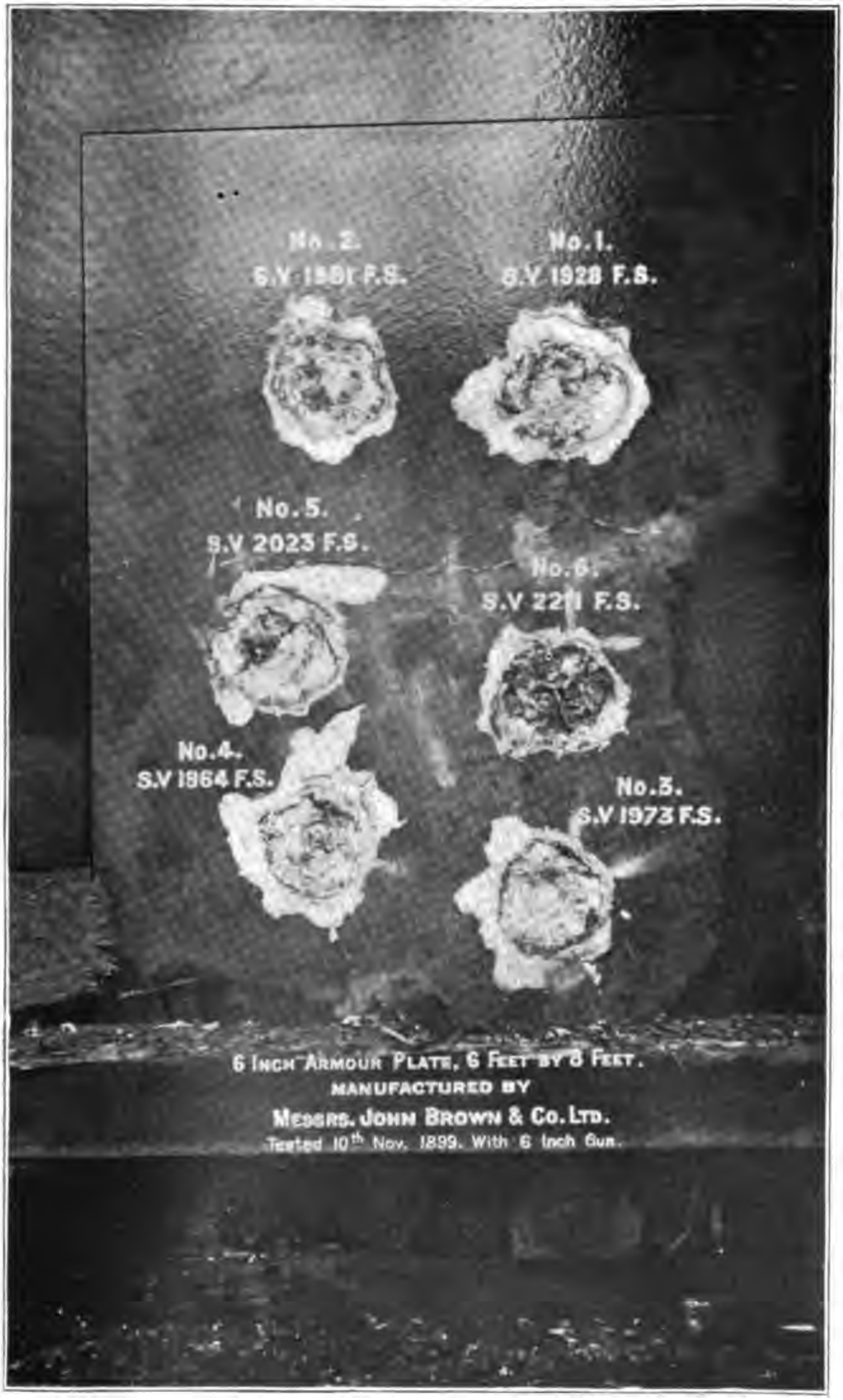
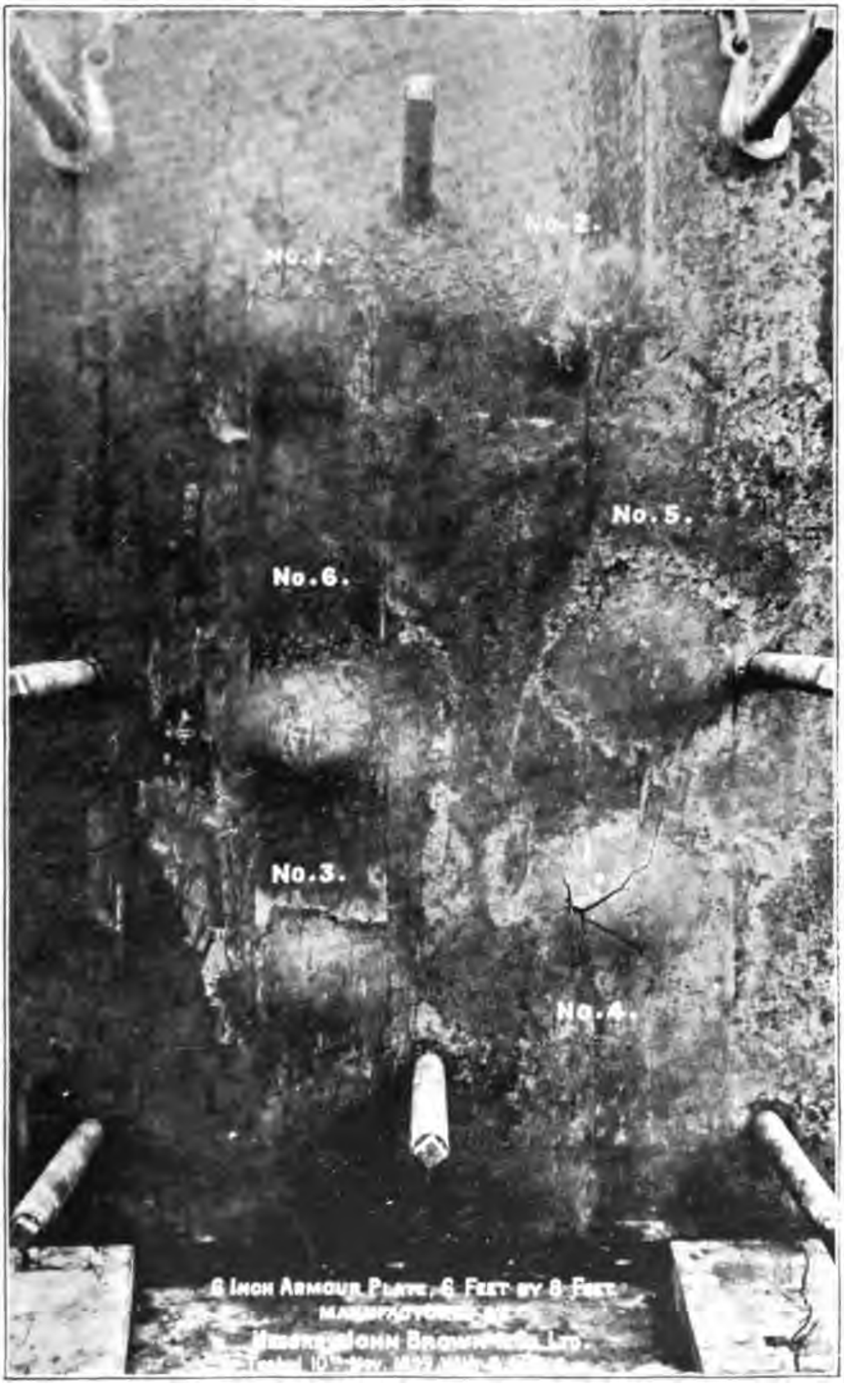
[1] Could not be measured, as point lodged in hole.



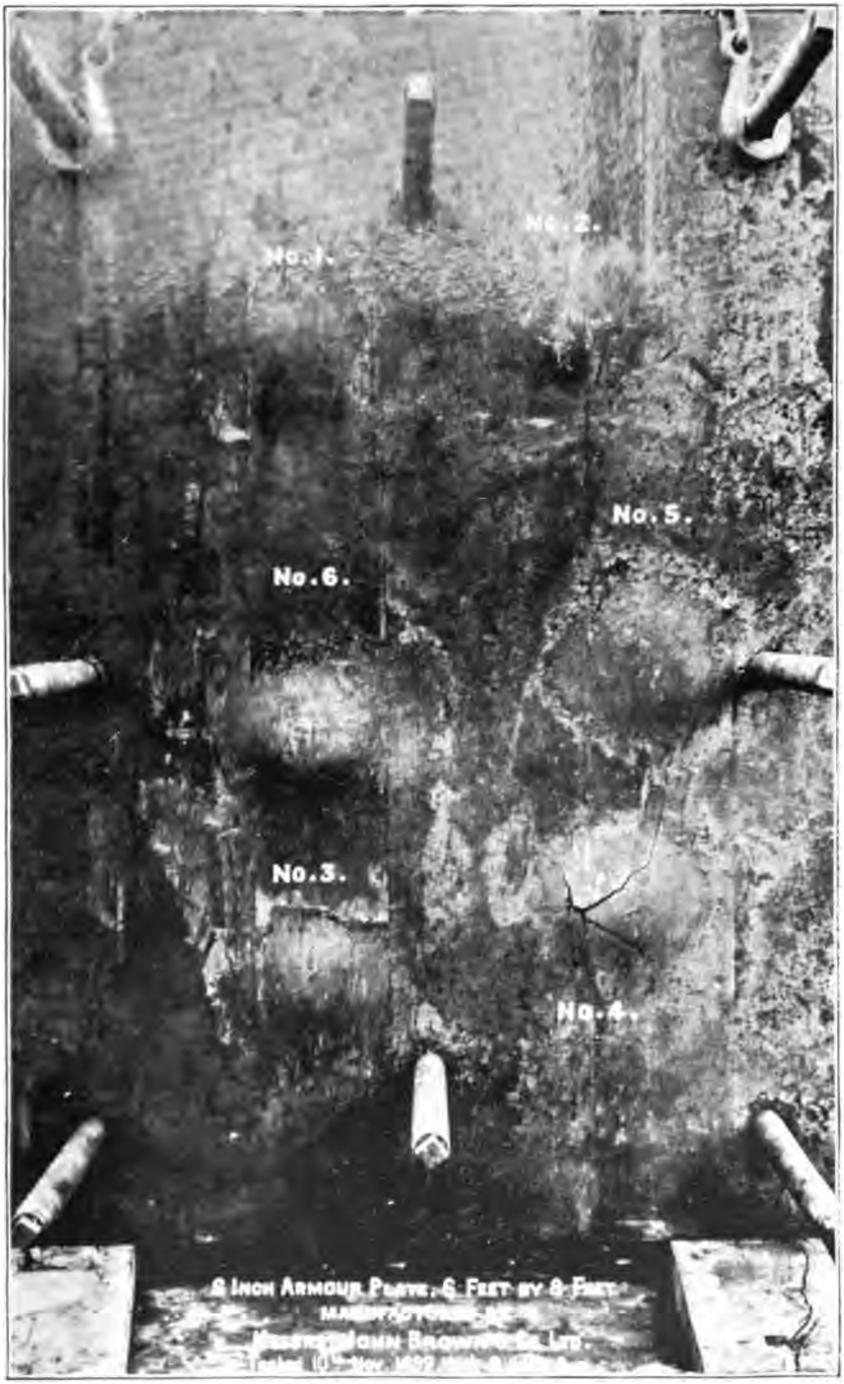
Face of plate after sixth round.

TEST OF PLATE FOR NORWEGIAN BATTLESHIPS NORGE AND EIDSVOLD.


No. 1.
No. 2.
No. 5.
No. 6.
No. 3.
No. 4.
6 INCH ARMOUR PLATE, 6 FEET BY 8 FEET.
MANUFACTURED BY
MESSRS. JOHN BROWN & CO. LTD.

Back of plate after firing

TEST OF PLATE FOR NORWEGIAN BATTLESHIPS NORGE AND EIDSVOLD.


No. 1.
No. 2.
No. 5.
No. 6.
No. 3.
No. 4.
6 Inch Armour Plate, 6 Feet by 8 Feet
Manufactured by
Messrs. John Brown & Co. Ltd.

Back of plate after firing

TEST OF PLATE FOR NORWEGIAN BATTLESHIPS NORGE AND EIDSVOLD.

SWEDEN.

As it has seemed not only impractical but inexpedient to separate Captain Grahm's interesting and instructive remarks on armor from the Swedish contract requirements and results of firing trials, the following extracts are given in full:

During the year 1899 the question of armor for our fleet has made a big stride forward toward solution, and the principle—no doubt the only correct one—that the best possible protection should be provided for our fighting ships was applied when the contract was made for the armor intended for our new battleships. It is both right and natural that under such circumstances the question of expense should not be the first consideration.

When bids were called for in July, 1899, for the armor for said ships the naval administration made such high requirements as to the trials that they could be satisfied only by the best armor plate in the market, namely, the so-called Krupp armor. The great "armor plate ring," which now comprises all the principal firms, made some slight modifications in the terms concerning the trials, but on the whole the requirements of the naval administration were accepted and the contract was awarded the world-renowned firm of Fried. Krupp, in Essen.

As the requirements referred to may be said to represent the present state of armor-plate manufacture, I will speak of this matter somewhat at length.

Formerly in estimating the resisting power of armor plate it was usually compared with wrought iron. The relation between the thickness of a wrought iron plate which is just able to keep out a certain projectile fired at a given velocity (usually computed by means of the Krupp or the Tresidder formula) and the thickness of the test plate just able to withstand the impact of such projectile was called the "relative value." This figure, which was 1 for wrought-iron plate and 1.1 to 1.2 for compound armor, has constantly risen until it now reaches 2, or even more. In other words, with only one-half the thickness of the plates that were used when armor was first introduced the same resisting power may be obtained against direct penetration. Whether the superiority of modern armor is still greater in the case of oblique fire is a question to be considered separately.

Of late the so-called de Marre formula has been generally adopted as the base for any computations as to the resisting power of armor plate. The formula is as follows:

$$Va. = 1530 \frac{d^{\frac{3}{4}} t^{0.7}}{\sqrt{p}}, \text{ in which}$$

Va. = striking velocity in m.
d. = caliber in dm.
t. = thickness of plate in dm.
p. = weight of projectile in kg.

This formula gives the striking velocity which must be given a projectile in order to just perforate a Creusot armor plate of soft steel. As the present methods of manufacturing armor make it possible to produce plates of considerably greater resisting power than possessed by the older Creusot plates, greater striking velocity can be required at trials than that stated in de Marre's formula. In order to indicate this progress, the maximum striking velocity with which a given plate can be attacked without penetration taking place is now expressed in percentage of the velocity which according to de Marre's formula is just necessary to perforate a soft-steel plate of the same thickness.

Applied to the best quality of Krupp armor, the percentage is 135 for plates of 150 millimeters and above and 138 for plates of 150 to 80 millimeters, the latter figure indicating the lowest limit of thickness to which the Krupp process, as concerns cementation, can be extended.

It is this percentage that forms the foundation for the requirements to be applied to the tests of the armor for our new battleships.

For armor trials a gun is usually chosen whose caliber is about the same as the thickness of the plate. The projectiles should be of the best chrome steel obtainable, but not capped. As to cracks produced in the plate during the trial, the requirement is that no through cracks shall occur. These requirements are embodied in the last Swedish contract with the firm of Krupp.

The manner in which the test plate is set up is of considerable influence on the result. The general rule has been adopted that the test plate shall represent the manner in which the completed armor is to be secured to the ship. Therefore the test plate of the citadel armor is usually provided with a backing of oak wood, while the test plate of the turret armor is set up against a thin-skin plate.

As to the number of trial shots, the requirements vary considerably in different countries. The Japanese Government, for instance, in a certain recent contract, requires but one shot to be fired against the plate, near its edge. Other navies require five shots, while certain navies have agreed on three shots for armor trial. Of course the dimensions of the test plate must vary according to the number of shots required, for as a rule the different shots are not permitted to be more than 3½ calibers from each other, and also that distance from the edge.

The requirements of the Swedish contract referred to are given in the following table:

Requirements of Swedish contract.

Plate intended for—	Type of plate.	Dimensions of plate.	Number of shots.	Caliber of gun.	Weight of projectile.	Striking velocity.	Per cent according to de Marre's formula.	Relative value according to Tresidder.	Remarks.
		Meters.			*Kilos.*	*Meters.*		*Per cent.*	
Citadel	Krupp, cemented	2 x 1.5 x 0.175	3	15 cm	45.4	615	135	2.05	No through cracks shall occur. All projectiles to be of Swedish manufacture.
21-cm. turret	Krupp, cemented	1.8 x 1.8 x 0.19[1]	3	17 cm	78	546	135	1.95	
15-cm. movable turret	Krupp, cemented	1.5 x 1.5 x 0.125[2]	3	12 cm	20.5	620	138	2.2	
	Krupp, uncemented	1.5 x 1.5 x 0.063[3]	3	57 mm	2.7	456	107	1.5	
15-cm. stationary turret	Bofors nickel steel	Whole turret 100 mm. thick.	3	12 cm	21	400	104.5	1.44	

[1] Curved to a radius of 1.75 meters.

[2] Curved to a radius of 1.3 meters.

[3] Curved to a radius of 1.4 meters.

The requirements concerning cracks are of great importance, for it is obvious that the armor must in that respect possess considerable resisting power "in reserve" (coefficient of safety) in order not to risk failure at the trial, and by the tendency to crack the armor shows how much resistance it possesses against loaded shell.

In this respect the trials made by Krupp in 1895 against a 100-millimeter cemented plate are very instructive. On this occasion three shots were fired with 15-centimeter loaded shell against the plate in question without producing through cracks, both when the plate was perforated and when the striking velocity was not sufficient therefor.

The German navy makes the requirement for all armor trials that the test plate shall not only be attacked with projectiles of the caliber of the thickness of the plate, but also with a projectile of considerably smaller caliber as well as with one of considerably larger caliber. In accordance therewith, 15-centimeter Krupp armor, for instance, is tested not only with 15-centimeter projectiles, but also with 10 and 21 centimeter projectiles. Computed according to De Marre's formula, the velocity of 10-centimeter projectiles is very great, and it is, therefore, a good test as far as the *direct resisting power* of the plate is concerned, because the projectile does not succeed in fracturing until the cemented surface has been penetrated. On the other hand, the 21-centimeter projectile, which strikes with comparatively little velocity, tends preferably to crack the plate. Under these circumstances it is impossible for manufacturers to obtain the required resisting power simply by regulating the depth of the cementation. Metallurgic processes which would otherwise be unnecessary must therefore be resorted to.

It has been stated above that the cementing process is not applicable to plates of less than 80 millimeters thickness. It seems, however, that Krupp has found a process of manufacture which may be applied also to thinner plates and increases their resisting power in a high degree. They are thereby enabled to withstand the attack of projectiles with a striking velocity of about 120 per cent, computed according to De Marre's formula. These plates are called in England "Krupp non-cemented" (K. N. C.), while the cemented armor is named after the manufacturer and inventor, as "Cammell-Krupped," "Brown-Krupped," etc. In France the cemented armor is called "acier cementé type Krupp."

In order to facilitate the lengthy calculations of velocity, thickness of plate, etc., so-called computing rulers have been constructed for the different formulas. There are such rulers, for instance, for Tresidder's formula, the result of which is similar to Krupp's, for De Marre's formula, and others.

The Krupp process is not patented, and is partly kept secret. The general features of the manufacture are as follows: The steel is produced according to the Martin process, with a comparatively large percentage of chrome or nickel, while the percentage of carbon is extremely small. From the casting of the steel in a parallelopipedal block until it is ready for rolling into plates it must not be allowed to cool. The cementing (that is, the hardening of the outer surface with carbon) is done by means of illuminating gas (lately Krupp is said to have used acetylene gas for cementing) in a large furnace specially constructed for that purpose, and this part of the manufacture may be considered one of the "corner stones" of the process. By the Krupp process the depth of the cementing at different places of the plate is much more uniform than is the case in the Harvey process, which, moreover, requires about three weeks, while Krupp's cementing process requires only half that length of time.

After the cementing the plate is allowed to cool and is then bent to the required curvature and cut off to the right dimensions. Then follow the hardening processes. These comprise hardening at a high temperature in water, oxidating in the same liquid, and hardening in oil at a moderate temperature. In order to maintain the back of the plate as soft as possible, certain oxidating processes are gone through.

The cemented part of the armor becomes glass hard, and emery disks must therefore be used for trimming the edges, etc. The most tedious work, however, is the correcting of the curvature, which is done under strong hydraulic pressure with the plate slightly heated.

The equipment of a plant for the manufacture of Krupp armor is extremely expensive. Almost all principal firms, however, which produce armor, on the continent of Europe, as well as in England and the United States, have acquired from Krupp the right to manufacture this type of armor. Owing to the expensive equipment of the plant, this armor plate is naturally very high-priced. But if we take into consideration the superior resisting power of Krupp armor over other types, the price is not so very excessive.

The following table gives the prices of the citadel armor of Swedish battleships and the striking velocities employed at trials, thus showing the relation between the increase in price and the greater resisting power:

Ship.	Place of manufacture of armor.	Thickness of plate in mm.	Per cent of striking velocity according to De Marre.	Relative value according to Tresidder.	Price per ton, crowns.[1]	$\frac{b}{a}$
			Per cent.	*a*	*b*	
Svea	Le Creusot	150	100	[2]1.88	1,066	770
Göta	do	244	96	1.55	1,066	688
Thule	do	250	96	1.25	1,066	855
Oden	do	250	96	1.25	1,170	938
Thor, Niord[3]	Sheffield	200	120	1.7	1,500	882
Dristigheten	St. Chamond	200	121	1.75	1,829	1,040
New battleships	Essen	175	185	2.06	[4]1,879	917

[1] One crown equal $0.268. [2] Cast-iron projectile. [3] Refers to turret armor. [4] No cracking effects.

In connection with the foregoing table it should be noted, however, that the striking velocity as therein given is that stipulated in the contract and that—since in none of the cases strict penetration took place—the *true* relative value of the armor is considerably larger than stated.

The British as well as the German navies are now using exclusively armor manufactured according to the Krupp process. The Russian navy uses both Krupp and Harvey armor, while in France, presumably for considerations of price, Krupp armor has not been adopted. As the firm of Krupp collects a large royalty on every ton of armor manufactured according to its process, the unwillingness of the French Government to adopt this type can be readily understood.

The hopes we have harbored for some years for the development of our home manufacture of armor were founded on the results obtained in the casemate armor for the battleship *Oden*, which were very creditable for the state of armor manufacture at that time. But the appearance and development of cemented armor has defeated our hopes of being able for the present to produce at home the complete armor equipment of our battleships. For the thinner armor of 100 millimeters and below we continue, however, to use Bofors material, on account of its softness and low price. The advantage of being able to make the stationary 15-centimeter turrets in a single piece was taken into consideration when the Bofors works were awarded the contract for the manufacture of all such turrets for the new battleships.

It is extremely desirable, however, to improve our process of manufacture so as to attain a resisting power approaching that of the K. N. C. armor. To determine the degree of superiority of the last-mentioned armor plate, comparative armor trials are being made.

the striking velocity required for penetration upon normal impact multiplied by the cosecant 1.5 for the angle between the axis of the projectile and the plate (according to Von Schrader). In order to illustrate the importance of this, let us assume the angle of impact to be 60 degrees, and in battle it will more frequently be less than more. The velocity required for penetration under such circumstances is 24 per cent greater than that required for penetration upon normal impact. In other words, the 17.5 centimeter Krupp armor belt of the new battleships, which may be perforated even at a distance of over 4,000 meters upon normal impact by a 21-centimeter gun of a similar ship, will resist the fire of the same gun at an angle of impact of 60 degrees at a distance of 2,000 meters. When the angle of impact decreases below 60 degrees a very great surplus of energy is required before penetration will take place.

This fact in itself warrants the reduction which is being made everywhere in the thickness of armor, as may be observed in all modern battleships, and which makes it possible to distribute the protection over a greater area. But might not such a proceeding increase the fighting value of heavy guns? In one navy, at least, the Italian, this question has been answered in the affirmative; for on board the two latest first-class battleships, the *Benedetto Brin* and *Regina Margherita*, there have been installed, besides the two (four) 30-centimeter guns, ten (eight) 20-centimeter guns, in order to make it possible to penetrate in battle the 15-centimeter Krupp armor which has come into such general use and to which the 15-centimeter R. F. guns are not equal. In the United States Navy, also, warning voices have been raised against the rejection of the 20-centimeter guns, which are found on board the battleships of the *Iowa* class and others, but are absent from the latest battleships of the *Maine* type. Many men are even of opinion that the present superiority of armor can be overcome only by increasing the medium-caliber armament, and that we may possibly witness in the future another contest between the caliber of guns and the thickness of armor plate similar to the one one which took place in the 70's and 80's.

ITALY.

Firing trials have recently been conducted at the Terni Steel Works, Muggiano, Italy, against armor plates face-hardened by a new process. The following is an extract from the official report received by the minister of marine:

> Three plates were tested, one of 11 centimeters thickness, and two of 6.7 centimeters each. The requirements of the contract were, for the 11-centimeter plate, 3 shots with 12-centimeter shell, at an initial velocity of 575 m. s.; for the 6.7-centimeter plates, 3 shots with 7.6-centimeter shell, at an initial velocity of 574 m. s. The results have surpassed all expectations. The projectiles did not perforate the armor, nor produce noteworthy cracks. The same results were attained with two additional shots against each plate with still more powerful projectiles.

It is understood that these plates will be sent to the Paris Exposition.

IV.

ENGINEERING NOTES.

By Lieutenant LOUIS R. DE STEIGUER, United States Navy.
Staff Intelligence Officer.

BOILERS.

The English press is actively discussing the great amount of repairs required by the men-of-war using Belleville boilers. According to these accounts, after a period of eighteen to twenty months in commission, it has been found necessary to send such ships to the dockyards and to spend months in repairing and retubing the boilers. The *Terrible* has had over $50,000 expended upon boiler repairs. The *Diadem* was fitted with Belleville boilers with economizers, and after being in commission less than two years was laid up for an extensive overhauling and retubing of her boilers. A great number of pin holes were found in the economizer tubes and over $20,000 were expended in boiler repairs. The boilers of the *Powerful*, which has just returned from South Africa, are reported to be in bad shape and to require an extensive retubing. The cable reports upon the recent arrival of the *Europa* at Sidney contain some very interesting data upon the unprecedented coal consumption of this vessel on her trip out from Portsmouth. The *Europa* has 30 Belleville boilers fitted with economizers. She occupied forty-nine days under steam on the above passage, consuming about 6,000 tons of coal.

In answer to an inquiry in the House of Commons as to the longest time that the water-tube boilers of any of Her Majesty's ships had been under continuous working at full power at sea without developing defects, and the consumption of coal per horsepower developed, the first lord of the admiralty said in reply:

> The longest run under continuous seagoing full power is that of the *Diadem* in December, 1898, when she was under way for sixty-nine hours for a distance of 1,330 knots, at an average indicated horsepower of 14,268 and an average speed of 19.27 knots. The coal consumption for all purposes was 2.16 pounds per indicated horsepower. No defects were developed during the run, the power and speed being maintained up to the end. The *Powerful*, which left for the China station in 1897, has in the course of her commission gone through speed trials which, though of shorter relative duration, are of equal interest. In a run from Honkong to Manila, in March, 1899, she steamed for twenty-seven hours a distance of 540 knots at an average speed

of 20.2 knots, and an indicated horsepower of 19,600. Her coal consumption was 2.6 pounds per indicated horsepower for all purposes. No defects were developed. In regard to the four hours' full-speed trial, the Captain wrote: "We averaged over 23,000 horsepower and were well over 24,000 horsepower one hour, and the average number of revolutions for the last four hours was just over 110 per minute, which in smooth water would give over 21.5 knots. Engines and boilers worked perfectly." * * *

The following table, taken from a parliamentary return, shows the cost of repairs upon the Belleville boilers of the vessels named since they were commissioned up to February 24, 1900.

Ships.	Date of first commissioning.	Labor.	Materials.	Total.
Diadem	July 19, 1898	£3,184	£1,034	£4,218
Niobe	December 6, 1898	136	238	374
Arrogant	January 27, 1898	3,021	1,490	4,511
Furious	July 1, 1898	1,208	396	1,604
Powerful	June 8, 1897	1,268	710	1,978
Terrible	June 15, 1897	6,652	3,804	10,456

In view of the controversy in England over the Belleville boilers, great interest was aroused by the competitive trials carried on by the *Minerva* and *Highflyer*. Foreign governments have also watched these trials with great interest, owing to the fact that many of their ships are fitted with Belleville boilers. Large and small, England has over 50 vessels supplied with them, France about 40, and Russia about 30. In addition to these countries, so largely represented, Austria, Italy, Argentine, Spain, Chili, Germany, and Japan have some of their ships supplied with them.

On the *Highflyer-Minerva* trials the *Highflyer* burned more coal at all speeds, amounting to 16.5 per cent more on the lower speeds. This would give that vessel a much smaller steaming radius at those speeds. After each trial the *Minerva*, after having her tubes and furnaces cleaned, was ready for sea. On board the *Highflyer*, after several of her trials, about 100 leaking joints had to be made tight. and she was, in consequence, laid up for several days.

The behavior of the Belleville boilers has caused many questions to be asked in Parliament, and the following extracts are taken from a memorandum presented to both houses of Parliament upon their conduct in English men-of-war. This memorandum gives the reasons for adopting the Belleville boilers the results of the trials, and the conclusions.

MEMORANDUM ON WATER-TUBE BOILERS.

This statement deals only with ships fitted with Belleville boilers or with boilers of large-tube types.

The use of small-tube boilers has been hitherto confined in Her Majesty's navy to third-class cruisers and smaller vessels, where the importance of securing a high speed on small dimensions justifies the acceptance of boilers which have a shorter life than is desirable for large ships.

The tubes of small-tube boilers are much thinner than those of the large-tube types, and the maximum power of the boilers is obtained by forcing, which also tends to shorten their life.

The experience gained with these boilers up to the present in destroyers, torpedo gunboats, and third-class cruisers does not, in the opinion of the Admiralty, justify their use in larger ships, though they have been adopted for this purpose in France and some other foreign navies.

The Admiralty policy has been to consider the Belleville boiler, with which they have had more experience than any other type of water-tube boiler, as the approved type for large ships, treating other types as experimental until they have shown that they possess some distinct superiority.

There are substantial advantages in adhering as far as possible to one principal type for all ships, as the whole service becomes quicker accustomed to its use, artificers, both in the ships and dockyards, become more expert in its repairs, and there is to a large extent interchangeability of the spare parts and accessories which have to be kept in store.

Two long series of trials have been carried out, in the *Sheldrake* and *Seagull,* with the Babcock and Wilcox and Niclausse boilers, respectively, for comparison with those previously carried out with Belleville boilers in *Sharpshooter.*

Each of these boilers has its advantages and drawbacks, but the trials showed no decided advantage of either over the Belleville boiler.

The experiments were, however, considered to justify further trials of both these boilers on a larger scale, and it has been decided to fit the Babcock and Wilcox in one of the new sloops, and possibly in one of the two new second-class cruisers, and the Niclausse in a new sloop and in a first-class cruiser of the *Monmouth* type.

This will give a fair trial of these two types of boilers on a sufficient scale in the future, but in this paper it is only necessary to compare the Belleville boiler with the cylindrical boiler.

HIGHFLYER AND MINERVA TRIALS.

The trials of the *Highflyer* and *Minerva* form the most direct comparison we have yet been able to make between the performances of Belleville and cylindrical boilers under ordinary sea-going conditions.

The two ships are identical in form and external dimensions, and the principal features of their machinery are described in Table III.

The difference in total weight of the machinery and boilers in the two ships is about 100 tons, which saving of weight in the *Highflyer* has been devoted to giving her six 6-inch guns instead of 4.7-inch.

The *Minerva* had been previously employed on relief service to China and in manœuvres, during which service she had a good deal of trouble with her machinery, but the defects then brought to light had been remedied, and at the time of the trials her machinery was in excellent condition; and as she had been some months in commission with a crew turned over from the training squadron, her engine-room staff was well trained.

The *Highflyer* had been only recently commissioned for the first time, and, with few exceptions, the crew had had no previous experience with Belleville boilers.

An inspector of machinery, who had had considerable experience with Belleville boilers in the Channel squadron, was sent out in connection with the trials, but was ordered in the first place to remain on board the *Minerva,* so that the management of the machinery in *Highflyer* might be under exactly service conditions.

The following trials were carried out in the order shown, the results being given in the attached Tables I and II:

A series.—Three runs, each of sixty hours' duration, at 10 knots, which, as regards machinery, were continuous and practically formed one run of 1,800 miles, the boilers being changed for each separate run of 600 miles.

B series.—Two runs, each of sixty hours' duration, at 14 knots, which, as regards machinery, were continuous and practically formed one run of 1,680 miles.

C_1 trial.—One run of sixty hours' duration, at 17 knots.

C_2 trial.—One run of thirty-eight hours' duration, at 17 knots. (This trial was then discontinued, owing to defects described in Table II having developed in *Highflyer*.)

The *Highflyer*, after refit, made an experimental run at 10 knots, with the inspector of machinery on board, and, on completion of this, made a further trial of sixty hours' duration under the conditions of the A series, with a considerably reduced coal consumption (see table).

An attempt to complete the C series was discontinued after eight hours, owing to hot bearings in *Highflyer*, but after refit this run was completed (see C_2 repeat trial).

D series.—Two runs of thirty hours' duration at the highest power obtainable.

E series.—Two runs in which *Highflyer* started with 6 boilers alight out of 18 and remainder not lighted. *Minerva* with 3 boilers alight out of 8 and fires in remaining boilers not lighted. At a given signal the fires were lighted as soon as possible in the boilers not in use, and the highest speed possible was maintained for twelve hours from the time of the signal.

F series.—One run at 10 knots for sixty hours, and then to be increased to full speed at an uncertain time. *Highflyer* with 6 boilers alight and fires laid in remaining boilers. *Minerva* with 3 boilers alight and fires alight, but banked, in the remaining boilers. After completing 65$\frac{1}{3}$ hours the signal was made and the remaining fires were lighted in *Highflyer* and spread in *Minerva*, so as to obtain full power as soon as possible, in order to continue at maximum power for twelve hours, but after 1$\frac{43}{60}$ hours *Highflyer* developed defects in one of the air pumps, which caused the trial to be discontinued.

During the earlier trials the coal expenditure in the *Highflyer* was found to be very much in excess of that in the *Minerva*, and so large, compared with the results obtained on her contractors' trials, as to indicate either serious defects or want of skill in the management of the fires.

The inspector of machinery was therefore directed to proceed on board the *Highflyer*, after trial C_2, and the ship was sent to sea by herself to work independently for the purpose of training the stokers.

After twenty-four hours of this training, trial A was repeated, when it was found that the expenditure was reduced from 3.45 pounds per I. H. P. for all purposes, which was the average of the three preceding similar trials, to 3.16 pounds per I. H. P.

The *Minerva's* average expenditure for the three A trials was 2.96 pounds per I. H. P., showing the excess expenditure of *Highflyer* over *Minerva*, at the low speed of 10 knots, to be 6.7 per cent.

Before this training was carried out the excess expenditure of *Highflyer* at this speed had been 16.5 per cent on the average of the three A trials.

The same difference is shown at 17 knots, if the average expenditure in C_1 and C_2 before the training is compared with C repeat after the training, the excess in the former case being 15.9 per cent and in the latter 6.7 per cent.

The coal expenditure in the *Highflyer* was still so considerably greater than it had been on the contractor's trials as to indicate that there were other causes of wasteful expenditure which had not been discovered; but the time during which the ships could be spared for the trials was limited, and it was not possible to make any further investigation at the time. During her refit at Devonport it was seen that the low-pressure slides and faces were much worn and not bearing satisfactorily, which would account for considerable loss of economy.

After this refit it was found that her expenditure on passage to the East Indies was, from Plymouth to Gibraltar, at 12.4 knots, 2.74 pounds per I. H. P. for all purposes, and from Gibraltar to Malta 2.67 pounds, at 13.16 knots, which shows a considerable improvement.

Just previously to this the *Diana*, a similar ship with cylindrical boilers, made the same passage in the opposite direction while returning from Australia. The speed and coal expenditure of the two ships compare as follows:

	Malta to Gibraltar, or vice versa.				Plymouth to Gibraltar, or vice versa.			
Ships.	Distance in miles.	Speed.	Coal per I. H. P.	Total coal used.	Distance in miles.	Speed.	Coal per I. H. P.	Total coal used.
		Knots.		*Tons.*		*Knots.*		*Tons.*
Diana	1,023	12	2.94	207	1,072	12.6	2.85	235
Highflyer	1,023	13.16	2.67	191	1,072	12.4	2.74	215

Diana's port engine was stopped for five hours between Gibraltar and Plymouth.

The most important point, however, which had to be determined by the trials was the maximum speed that could be maintained at sea under ordinary service conditions. It is, therefore, the trials at this maximum speed which are most important.

In the design of machinery for a man-of-war the main problem is how to combine certain conditions of armament, protection, coal endurance, etc., with sufficient speed to catch the enemy's ships when they are sighted at sea.

Trials D_1 and D_2 at the highest speed obtainable for thirty hours show an advantage in speed of 0.37 of a knot in the first and 0.94 of a knot in the second in the favor of *Highflyer*, and this was confirmed by trials E and F.

The I. H. P. exerted by *Highflyer* was 396 more than *Minerva* in D_1, and 1,382 in the other trial, and if *Minerva's* machinery were to be redesigned to give this increased power, retaining cylindrical boilers, it would have to be from 47 tons to 170 tons heavier.

Moreover, the boilers and machinery would require more space, and this would require a larger ship with increased weight of hull, which would again necessitate more I. H. P. and consequently a further increase of weight to maintain the same speed. This would, of course, be in addition to the 100 tons already gained in *Highflyer*.

The trials E and F, which were intended to show the advantage of the water-tube boiler in rapidly raising steam, were largely in favor of the *Highflyer*, except as regards the accident which stopped trial F. This is a point only second in importance to that of maintaining the maximum speed. It is sometimes said that a captain in war will never let his fires out, but there will be many cases in which he must do so, both for the sake of the overhaul, cleaning, and repair of his machinery and boilers, and also when it is of vital importance to husband his supplies of coal.

TABLE I.—*H. M. S. Minerva—Results of special trials.*

Description of trial.	Date.	Duration of trial.	I. H. P.	Speed.	Revolutions.	Draught of water.				Number of boilers in use.	Coal consumption per I. H. P. per hour, all purposes.	Water.			Remarks, defects, etc.
						Forward.		Aft.				Used from reserve tank.	Distilled for machinery	Distilled for ship.	
		Hours.		*Knots.*		*Ft.*	*in.*	*Ft.*	*in.*		*Pounds.*	*Tons.*	*Tons.*	*Tons.*	
A_1	1-3.1.1900.........	60	1083.8	9.84	66.5	19	10	23	7	3 and 4	2.88	....	5	15	
A_2	3-6.1.1900.........	60	1084.5	9.89	66.19	19	6	23	4	4	3.02	....	5	15	
A_3	6-9.1.1900.........	60	1084.95	9.98	65.98	19	1	23	1	4	2.99	....	5	15	
B_1	13-16.1.1900.......	60	3028.1	14.00	93.47	19	11	23	5	6	2.33	....	7.5	23	
B_2	16-18.1.1900.......	60	3169.0	13.93	94.2	18	11	23	2	7	2.24	....	10	22	
C_1	24-26.1.1900.......	60	6242.35	17.15	117.92	18	9	23	1	8	2.28	....	20	6	S. H. P. cylinder cover leaked badly.
C_2	30.1.1900 to 1.2 1900.	38	6022.8	17.05	117.1	19	0	23	3	8	2.25	....	9	....	S. L. P. slide-rod gland leaked badly. Trial curtailed on account of defects in *Highflyer*.
C_3 ...... Repeat .	28.2.1900 to 3.3 1900.	60	6021.7	17.0	117.3	19	2	23	1	8	2.22	....	15	....	No defects. This trial is a repetition of two former trials.
D_1	6-7.3.1900.........	30	7550.2	17.53	123.9	19	3	23	2	8	2.23	20	24	....	Forward main feed suction pipe burst. S. H. P. piston-rod gland leaked badly.
D_2	10-11.3.1900.......	30	7379.2	18.03	123.6	18	2	22	11	8	2.16	....	12	....	Starboard main feed suction pipe burst.
E_1	17.3.1900..........	13$\frac{41}{60}$	6778.16	16.98	119.8	19	6	23	3	8	2.16	....	2	....	
E_2	20.3.1900..........	13$\frac{11}{60}$	6510.3	16.83	117.3	19	0	23	0	8	2.11	....	2	....	
F.......	24-27.3.1900.......	65$\frac{48}{60}$	1132.0	10.0	66.1	19	10	23	3	3 to 8	3.09	....	5	....	No defects. Trial at full power discontinued at end of 1$\frac{[illegible]}{60}$ hours, on account of defects in *Highflyer*.

TABLE II.—*H. M. S. Highflyer—Results of special trials.*

Description of trial.	Date.	Duration of trial.	I. H. P.	Speed.	Revolutions.	Draught of water.				Number of boilers in use.	Coal consumption per I. H. P. per hour, all purposes.	Water.			Remarks, defects, etc.
						Forward.		Aft.				Used from reserve tanks.	Distilled for machinery.	Distilled for ship.	
		Hours.		*Knots.*		*Ft.*	*In.*	*Ft.*	*In.*		*Pounds.*	*Tons.*	*Tons.*	*Tons.*	
A_1	1-3.1.1900	60	1,190.5	9.8	86.35	[1]19	8	22	11	6	3.46	....	42	19.5	2 generator door joints and 7 economizer door joints leaky; 2 fusible plugs renewed. These defects caused 1 boiler to be out of use 4¾ hours.
A_2	3-6.1.1900	60	1,205.5	9.9	85.9	to		to		7	3.38	....	46	12	2 economizer door joints leaky and 4 fusible plugs renewed. These leaky doors caused 1 boiler to be shut off and another substituted.
A_3	6-9.1.1900	60	1,137.4	9.98	85.85	[2]18	9	21	6	[3]8	3.50	....	48	19	Joints of 2 doors leaky, causing 2 boilers to be shut off.
A Repeat.	14-17.2.1900	60	1,101.9	9.82	85.89	20	0	22	2	5	3.16	....	16	14	No defects developed. This trial was a repetition of the 3 previous trials.
B_1	13-16.1.1900	60	2,831.5	14.0	120.9	[1]20 to	6	22 to	5	12	2.90	....	44	10.5	Starboard evaporator feed-pump rod and crosshead defective.
B_2	16-18.1.1900	60	3,132.4	13.9	122.75	[2]18	3	21	7	12	2.87	6	68	21	10 joints in main steam pipe and many smaller joints leaky; 12 fusible plugs renewed.
C_1	24-26.1.1900	60	5,750.4	17.15	158.75	19	2	22	2	18	2.67	16	52	6	Crank shaft of P. distilling engine was broken on two occasions. S. crank-pit pump, connecting and pump rods broken and barrel cracked. H. P. cylinders, 3 stays for supporting cover found broken after trial.
C_2	30.1.1900 to 1.2.1900.	38	5,707.8	17.05	152.6	19	11	22	6	18	2.58	14	44	....	Crank shafts of both distilling engines broken. S. I. P. crank-head bearing heated, causing curtailment of trial, and spare brasses were fitted.

[1] Draught at commencement of trials.

[2] Draught at end of trials.

[3] Decreased to 6.

TABLE II.—*H. M. S. Highflyer—Results of special trials*—Continued.

Description of trial.	Date.	Duration of trial.	I. H. P.	Speed.	Revolutions.	Draught of water.				Number of boilers in use.	Coal consumption per I. H. P. per hour, all purposes.	Water.			Remarks, defects, etc.
						Forward.		Aft.				Used from reserve tanks.	Distilled for machinery.	Distilled for ship.	
		Hours.		*Knots.*		*Ft.*	*In.*	*Ft.*	*In.*		*Pounds.*	*Tons.*	*Tons.*	*Tons.*	
C_2 Repeat.	28.2.1900 to 3.3.1900.	60	5,907.0	17.0	152.05	20	0	22	6	15	2.37	....	45	....	End door of steam drum on No. 13 boiler leaky. Top of float box of No. 18 boiler defective. Several joints in main and auxiliary steam pipes leaky.
D_1	6–7.3.1900........	30	7,946.3	17.9	164.35	19	5	22	6	18	2.52	10	50	....	Impeller shaft of S. auxiliary circulating pump broken. A few joints in steam pipes leaky; 16 fusible plugs renewed.
D_2	10–11.3.1900.......	30	8,760.9	18.97	170.48	18	0	21	11	18	2.58	43	50	....	2 joints in main steam pipe leaky. Impeller of S^d. auxiliary circulating pump worked loose on shaft; 30 fusible plugs renewed. On subsequent examination junk ring keep of P. A. L. P. piston was found broken.
E_1	17.3.1900..........	$12\frac{16}{60}$	9,132.1	18.08	171.2	19	10	22	6	18	2.36	10	12	....	P. I. P. crank-head bearing heated, spare brasses fitted; 1 fusible plug renewed.
E_2	20.3.1900..........	$12\frac{17}{60}$	9,268.2	18.71	171.55	18	8	22	4	18	2.47	10	12	....	P. H. P. and P. I. P. crank brasses worked warm; 1 fusible plug renewed.
F	24–27.3.1900.......	$65\frac{33}{60}$	1,235.7	9.99	85.9	19	10	22	6	6	3.06	....	40	....	Bucket of P. air pump loose on rod, causing damage to webs of bucket and guards of valves. This caused the full-power trial to be discontinued after $1\frac{33}{60}$ hours.

NOTE.—On 9.2.1900, after steaming twenty-four hours at 10 knots for the purpose of training the crew, the shafts of both auxiliary circulating pumps broke.

TABLE III.—*Particulars of machinery of Minerva and Highflyer.*

Machinery.	Minerva.	Highflyer.
Engines:		
Type	Triple expansion (3 cylinders)	Triple expansion (4 cylinders).
I. H. P., maximum	9,600	10,000.
Revolutions	140	180.
Stroke	3′ 3″	2′ 6″.
Boilers:		
Type and number	Tank; 8 in number	Belleville; 18 in number.
Steam pressure	155 pounds at boilers, 150 pounds at engines.	300 pounds at boilers, 250 pounds at engines.
Weight:		
Main and auxiliary machinery.	380.1 tons	373.8 tons.
Boilers	557.8 tons	461.5 tons.
Total (ready for steaming).	937.9 tons	835.3 tons.

TRIALS OF HERMES AND DIANA.

Another series of trials of a different character was made between two other ships of the same classes as *Highflyer* and *Minerva*, respectively, with the object of separating the performance of the boilers from that of the machinery.

The results of these trials are given in Tables IV and V.

It is impossible under ordinary conditions of steaming to separate the waste of heat due to the boiler from the waste of heat and steam that occurs in all parts of the main and auxiliary machinery.

In order to separate the performance of the boilers from that of the machinery, the *Hermes* (whose machinery is identical with that of the *Highflyer*) and *Diana* were fitted with tanks for measuring the quantity of water passing through the main and auxiliary condensers.

At the higher powers the quantity of water passing through the engines and the coal consumption were both less in *Hermes* than in the *Diana*, whereas at the lower powers, although the coal consumption was still slightly less in *Hermes* than in *Diana*, the water used by the former was more, showing that the boiler was more economical, but more steam was used in the engines.

Higher pressures necessarily require greater perfection in all such parts as slide valves, piston rings, and stuffing boxes, as well as in all steam joints, as the higher the pressure the more steam will pass through any leak without doing useful work. The waste of steam from stuffing boxes and joints is generally visible, but that which passes through any defective piston rings and slide valves, in either the main or auxiliary machinery, can generally only be discovered by taking the machinery to pieces.

There is no doubt that economy largely depends on the stoking and on the boiler being free from deposits and in all respects in good order, but in many cases when the coal consumption has been large it has been found to be mainly due to defects in the machinery, which, under the conditions of naval service, are very difficult to discover, as Her Majesty's ships are always kept, as far as possible, ready for immediate service, and opportunities for opening up the machinery only occur at comparatively long intervals.

GENERAL OBSERVATIONS ON DEFECTS.

The adoption of water-tube boilers carried with it a great increase of steam pressure, namely, from 150 pounds to 250 pounds at the engines, and this involved alterations of detail in the designs of practically all the auxiliary machinery, as well as the main engines. It is in these details and in the precautions necessary for dealing with the higher pressures that the principal difficulties have occurred.

The principal defects from which the ships have suffered have been—

LEAKY JOINTS.

These occur principally in the early part of a ship's commission. A better method of making them is being introduced as they give out, and all serious trouble from this cause is generally got over after a ship has been some time in commission.

LEAKS IN CONDENSERS.

This is a defect that is not confined to water-tube boiler ships, and is not affected by the use of high-pressure steam, being principally caused by the splitting of condenser tubes. In new large ships the condensers are now being made in two parts, in order that one half may be overhauled and cleaned or repaired while the other is in use.

EVAPORATORS AND THEIR ACCESSORIES.

Leaky joints and other causes of waste of water have in many cases thrown too much work on these, but these difficulties rapidly disappear when the causes of abnormal waste are removed, and the evaporating plant is now being increased in all modern ships.

AUXILIARY CIRCULATING PUMPS.

Troubles have been experienced owing to the frequent fracture of the shafts of these engines; generally the fracture took place in the impeller shaft, but in addition to this, in the *Canopus*, the crank shaft also fractured, and so also did the engine bed. In the case of the *Canopus* entirely new engines have been fitted. The fractures of the impeller shafts in this and some other ships were largely due to defective material, although they were also of rather too small diameter for the work required of them. In these cases they have been replaced by the contractors under their guarantee.

AUXILIARY AIR PUMPS.

These have given trouble in some cases, owing to want of strength in the pumps or details of engines. In others the cause has been the inferior arrangement of the suction or discharge pipes, principally the latter. Stronger forms of double-crank pump are being fitted for this purpose for the newer ships. In the ships where this defect occurred it has been remedied either by fitting new pumps or making certain modifications in the existing pumps. This latter course was adopted in the *Goliath*, in which ship the connecting-rod bolts broke, the engine seats were not stiff enough, and the engines and pumps noisy and with a tendency to wear rapidly. The pump was altered from the ram to bucket type, lighter valves fitted, and the foot valves were omitted, the engine seat stiffened up, and the lead of discharge pipe improved, after which they worked more satisfactorily.

PISTON-ROD GLANDS LEAKING.

These have given trouble in some cases, especially in the earlier ships. In some cases it was probably due to the design not being suitable to the pressure. The principal cause is either want of adjustment of the packing or dirt obtaining access to the cylinder and cutting the working parts of the packing or rods. In the *Furious* considerable leakage of high-pressure glands was due to the scale from the boilers or steel castings being carried over by the steam and cutting the packing and rod.

FEED PUMPS.

These are all direct pumps without crank shafts. In one variety the sticking of the shuttle valve has often given trouble, causing the shuttle valve to work sluggishly, so that the engine is difficult to start and may slow down or stop. The cause is generally the presence of dirt, or if salt water is present in the boilers a deposit of salt is often left on these valves. An efficient lubricator is now fitted to them. The joints of the water and steam cylinders have also given trouble.

In the pumps of another design severe corrosion has been experienced in the slide valves and liners, causing these parts to become grooved and leak, so that the engine would not work properly. This was remedied by fitting forged bronze valves and liners, since which there has been no further trouble.

In the *Hermes* the pumps failed owing to their not having been efficiently overhauled and their defects ascertained and remedied.

Generally speaking, the feed pumps of our ships work well, but as in the new vessels they had to work at much higher pressure, leaks and other defects which would be of little importance with low pressure assume greater importance and can not be neglected.

DRAIN TRAPS AND DRAIN SYSTEM.

The system of drain pipes, drain traps, drain tanks, and drain-tank pumps fitted for dealing with water in the steam and exhaust pipes has given trouble in several ships. Defects are principally due to leaky joints in drain pipes, burst drain pipes, defective drain valves or cocks, defective drain traps which fail to work either by becoming choked up with dirt or by allowing steam to blow straight through. Serious losses of water and steam occur from failures in this system; also the temperature of water in the drain tank becomes excessive, and the drain-tank pump gives trouble and fails to pump out this water.

Considerable attention has been devoted to the design of an efficient steam trap, but it is doubtful whether any of them are so at present and if efficient when new they soon become deranged. In some recent ships considerable simplification of the drain system has been made, the drains for steam pipes, for instance, being fitted as simple pipes discharging into the bilge without being connected to any steam trap. This will involve more care being taken in raising steam, but will no doubt result in the saving of much annoyance and prevent much loss of steam, which seems to be inevitable in the old system.

MAIN-ENGINE SLIDE VALVES.

Where these have been of the flat type with relief rings at their back, trouble has been experienced in some ships owing to the inefficient action of the relief ring. They require very careful adjustment and great care taken to insure that the rings are capable of moving freely in their recesses. In the case of flat slide valves to intermediate pressure cylinders, their failure has often been accompanied by cutting of valves and faces. Flat slide valves have now been abandoned in the newer vessels for the intermediate cylinder, and valves of the piston type are fitted, these being free from this source of trouble. Cutting of faces of the flat slide valves on L. P. cylinders have also been experienced, but this has been generally due to the use of too soft cast iron.

In the boilers themselves the following defects have been the most common:

CORROSION OF THE BAFFLE PLATES IN STEAM COLLECTORS.

These, being made of thin plates, corrode rapidly, and the rust and scale are liable to be carried into valve seatings or other places where they may do harm, though the greater part of the scale is deposited in the mud drums. Modifications have been made in these fittings in *Terrible*, *Diadem*, *Furious*, and *Arrogant*, which it is expected will greatly reduce the amount of corrosion. New ships are being fitted similarly and completed ships altered as opportunities offer.

JOINTS OF DOORS LEAKING.

This occurred to a serious extent in the *Argonaut* during last year's manœuvres, due to the doors not being interchangeable and to unsuitable asbestos washers being used for making the joints.

Since suitable washers have been provided very little fresh trouble has arisen from this cause.

FLOAT GEAR OF AUTOMATIC FEED CORRODING.

Portions of these, specially liable to corrosion, have either been galvanized or bushed with bronze, as opportunities occur, and there has been very little trouble with them lately.

NON-RETURN VALVE IN DOWN COMERS.

The pins of these became corroded in the *Terrible* and the valves failed to act, but since attention has been called to them and they have been refitted no fresh trouble has arisen.

SUPPORTS FOR BACK ENDS OF TUBES GETTING HOT OR BURNING AWAY.

Such heating has happened in some cases, where they were insufficiently protected by the brickwork, or where the latter has been destroyed. For new boilers, and also in cases where old brickwork becomes defective, it is built up in an improved manner, and its behavior is then satisfactory.

NICKEL WASHERS LEAKING.

This is generally caused either by bending of the generator tubes, or the dropping of the back ends by the burning away of the supports at the back of the tubes, as above. When the supports are properly protected and the tubes are not allowed to get overheated from imperfect circulation or shortness of water, leakage rarely occurs. In any case the washers can be very quickly duplicated or replaced.

PITTING OF TUBES.

This occurred to a considerable extent in the *Diadem*, 13 tubes in all being pitted through. Methods of preventing it are under trial, namely, galvanizing the interior of the tubes, and the use of zinc rods; also more care is being taken to prevent the water from becoming acid by the use of lime.

LEAKY SAFETY VALVES.

These are a frequent source of trouble, which is increased with the higher pressures of steam. Leaving out the greater difficulty of making tight joints at high pressures, in many ships the cause has been the cutting of the valves and seats by scale and other foreign matter blown out of the steam collector. Where this has occurred, it has been remedied by having the steam collectors thoroughly washed out and the valves refitted.

With the newer machinery designs the simplification and galvanizing of the internal baffle plates will reduce the liability of leakage due to this cause, and as opportunities offer the steam collectors of the older designs are also being galvanized and simplified.

In a few cases the leaky safety valves experienced were due to defective designs which were not suited to the high pressure, and new valves were fitted.

BURSTING AND OVERHEATING OF BELLEVILLE BOILER TUBES.

Either bursting or overheating has occurred in the *Powerful*, *Terrible*, *Arrogant*, *Furious*, and *Hermes*. In new ships, on contractor's trials, when overheating has occurred, it has been principally through obstructions to the circulation of water by some foreign matter, such as wooden plugs or waste being left in the boilers. In a few cases, defects of manufacture have been the cause, especially before the manufacture of solid-drawn tubes was properly developed. This was the case in the *Powerful*. In ships in commission the cause has generally been either shortness of water or the presence of saline deposits in the tubes due to the admission of sea water, while the necessary blowing off to keep down the density under these conditions was neglected. This was the case in the *Terrible*. In the *Arrogant* there was a combination of these two causes. In the *Furious* only two very small splits occurred in two adjacent tubes. They were not observed until the boilers were examined after steaming. The tubes were clean, but the general appearance of the elements of which these tubes formed part showed that overheating was the cause. No doubt this boiler had been short of water.

With tubes of the quality now supplied to our boilers, provided solid deposits are excluded and the proper quantity of water is kept in the boilers, this source of trouble should be eliminated.

SALT WATER OBTAINING ACCESS TO BELLEVILLE BOILERS.

Cases have occurred in which sea water has been used in these boilers without much inconvenience, provided proper precautions are taken, but on the return voyage of the *Terrible* from Malta with relief crews, the undesirability of allowing any access of sea water was shown. Although, as stated above, sea water can be used if care and due precautions are exercised, yet the small quantity of water contained in the boilers renders the rise of density comparatively rapid and the danger of saline deposits correspondingly great, especially at low rates of combustion. In the *Terrible* many of the tubes were salted up and burst or were otherwise damaged. The sea suctions of all feed pumps have now been blanked off to prevent the unauthorized use of salt water, this and leaky condensers being the usual causes of salt water getting into the boilers.

The total number of tubes that have been removed as defective from each ship is given in Table No. VI.

It will be seen from this table that, excluding *Hermes*, which is an entirely exceptional case, most of the defective tubes occurred in the *Powerful*, *Terrible*, and *Arrogant*, which were the first ships commissioned. The greater part of these occurred in the earlier part of their commissions, when the management of the boilers was less understood.

Since the accident to the *Terrible*, in the previous paragraph, the number of tubes damaged has been very much reduced.

Table No. VII shows the total number that have become defective in the whole fleet since the date of that accident, excluding *Hermes*.

BOILER TUBES BEING PULLED OUT OF JUNCTION BOXES.

This has occurred in two ships, the makers of the boilers being the same in each case. It was due to the thread in the junction box being defective, and was a case of bad workmanship which the overseers had not detected.

FEED-COLLECTOR TUBES LAMINATED.

In a few cases laminations have developed in these tubes, principally on the fire side. The cause was defective manufacture.

Where this defect has occurred, however, it has not been such as to interfere with the steaming of the particular boiler. The laminated tubes have been removed and new ones fitted. These feed collectors are now being largely made from solid bars bored hollow.

SMOKE-BOX DOORS OF BELLEVILLE BOILERS DEFECTIVE.

These doors are found sometimes to warp and buckle under the influence of excessive heat, occasionally resulting in the bolts of the doors not entering properly into their sockets. This defect, if not remedied, causes a loss of economy in combustion. The overheating is generally due to inferior stoking. In the newer ships, the smoke-box doors are being made of smaller dimensions and of a stiffer design, which will reduce the tendency to this defect.

THE ADOPTION OF WATER-TUBE BOILERS IN FOREIGN NAVIES.

Practically all foreign nations may be said to have adopted water-tube boilers in some form or another, almost to the entire exclusion of cylindrical boilers.

France was the first in the field, and has adopted many different types.

The principal ones are the Belleville, Lagrafel D'Allest, Niclausse, Normand, Guyot, and Du Temple boilers, the last three being small tube types.

Germany has in some cases combined cylindrical with water-tube boilers of small tube types, either Thornycroft's or Schültz, which is similar. They have also the Dürr, Niclausse, and Belleville.

Russia has principally Belleville boilers, with a few Niclausse, Schültz, Normand, and other kinds.

United States have combined cylindrical with Babcock and Wilcox or other types in some of their ships. Their new vessels are all to have water-tube boilers. Two battleships under construction have Thornycroft boilers and one Niclausse.

Italians have Belleville or Niclausse in their large ships building.

Dutch have Yarrow or Yarrow in combination with cylindrical boilers.

Norway and Sweden principally Yarrow.

Japan, Belleville.

CONCLUSION.

Surprise is naturally felt by those who are not fully conversant with the whole of the circumstances, that difficulties connected with the management of water-tube boilers and high-pressure machinery should take so long to overcome, and they are apt to assume that because they are not all removed in the three or four years that have elapsed since water-tube boilers were introduced into the British navy they must be insuperable.

A little consideration will show that up to the present, and for some time to come, the engine-room staff of every newly commissioned water-tube boiler ship must be largely composed of those who have had no previous experience of this type of machinery, as the number of water-tube boiler ships in commission has up to the present borne so small a proportion to the total number of ships for which crews are provided. The rate at which crews can be trained will increase rapidly as more water-tube boiler ships become available, and as special arrangements for training engineers, engine-room artificers, and stokers augment the number of men with experience of these boilers.

When defects of any importance occur in any part of the machinery of new ships, the best method of dealing with them is considered, by the makers of the machinery, who are responsible for the design and have great interest in maintaining its efficiency, by the dockyard officers, who have the experience of all similar defects that have been dealt with at their own yard, and by the Admiralty engineers, who are in close touch with all the dockyards, as well as with all the contractors and the officers afloat.

For each defect the first thing is to determine the true cause, which is often difficult to ascertain. It must then be determined whether the defect might not be avoided if some different method of treatment was adopted, or some precaution to prevent improper management was introduced, and finally, if an alteration is to be made, what the alteration should be in each case. Each of these steps requires time for investigation and experiment, which must, as a rule, be carried out without interfering more than can possibly be helped with the service on which the ship is employed.

Alterations, when decided on, can only be carried out when the ship can be spared, which is generally only when she is in dockyard hands for other purposes, and the efficiency of each alteration must generally be tested by actual experience in one or two ships before it is carried out generally.

Improvement is, however, steady and continuous, and may be expected to become more rapid as all concerned, including the engineering staffs at the Admiralty, dockyards, and contractors' works, as well as the engineers of the ships, gain experience.

There is no doubt that the advance from cylindrical to water-tube boilers, with its accompanying great increase in pressures from 150 pounds to 250 pounds at the engines, has for the present added greatly to the anxieties of the engineers in charge of the machinery. This is inevitable when any change of this magnitude is made, involving as it does such a multitude of small details.

It should be fully recognized that these officers have at first a difficult task, and that time is necessary to enable them to gain experience in the best way of dealing with all emergencies that arise under the new conditions.

Most of the difficulties are got over after a ship has been some time in commission, especially if the service she is employed on permits of time and opportunity being given to remedy all the defects that are discovered; and the difficulties are all of such a nature that it may be confidently expected that they will be successfully overcome, by comparatively small modifications of design or manipulation, as expeperience is gained.

Men-of-war must be designed to cope with those of foreign countries that they may have to meet in war, and no country can afford to relinquish such a decided advantage in speed for a given weight as the trials of *Highflyer* and *Minerva* showed to be given by water-tube boilers, or the great advantage of getting up steam and increasing speed rapidly, unless there were strong grounds for supposing that the numerous defects in details which now render the machinery somewhat less reliable than older and well-tried types were likely to be permanent.

This is certainly not the case. All the experience in our commissioned ships shows that the defects from which they at first suffered are being rapidly overcome, and it is practically certain that if we were to revert to cylindrical boilers and accept the sacrifice of speed or increase of displacement that it would entail, we should find that before the first ship was completed all the difficulties of detail which now give us trouble in water-tube boiler ships will have been overcome, and all our new vessels would be distinctly inferior to those of all other countries, with no compensating advantages.

Taking the results of the *Highflyer's* and *Minerva's* trials as they stand, and putting the 100 tons of weight saved in the machinery of the former into horsepower instead of guns, the gain of speed due to the water-tube boilers under practical seagoing conditions can not be put at less than a knot, a result which is borne out in a general way by the comparisons of other runs of vessels with cylindrical and Belleville boilers, respectively, though in these cases equally precise conclusions can not be drawn from them, owing to the form and dimensions of the ships compared not being identical.

Thus, if the Admiralty of the day had not decided to put water-tube boilers into the *Powerful* when she was designed, or the subsequent successive boards had hesitated to follow their policy, and had waited until the whole of the minor difficulties involved in the change had been overcome, the magnificent fleet which has been built, building, and projected since that time, consisting of—

Battleships:		
Canopus'	6	
Formidables	8	
Duncans	6	
		20
Armored cruisers:		
Drakes	4	
Cressys	6	
Monmouths	12	
		22
Protected first-class cruisers:		
Powerfuls	2	
Diadems	8	
		10
Second-class cruisers:		
Arrogants	4	
Hermes'	5	
		9

making a total of 61 ships, would have had at least a knot less speed than they now will have, or an equivalent sacrifice would have had to be made in other directions, which, to gain a knot at the high speeds now necessary, would be very considerable in amount.

TABLE IV.—*H. M. S. Diana—Results of water-consumption trials.*

[Made in May and June, 1899.]

Description of trial.	Percentage of full power.	Steam pressure.			Pounds of water per I. H. P. per hour.			Pounds of coal per I. H. P. per hour.	Remarks.
		Boilers.	Engines, starboard.	Engines, port.	Main engines.	Auxiliary.	All purposes.		
Thirty hours at 800 I. H. P.	8.3	101	96	97	20.59	5.68	26.27	2.82	
Twelve hours at 1,600 I. H. P.	16.6	124	120	121	18.94	4.21	23.15	2.52	Cut-off in H. P. cylinder 38 per cent.
Thirty hours at 1,600 I. H. P.	16.6	117	113	113	18.26	3.29	21.55	2.52	Cut-off in H. P. cylin-44.5 per cent.
Thirty hours at 4,800 I. H. P.	50.0	133	128	128	17.09	2.14	19.23	2.02	
Thirty hours at 6,400 I. H. P.	66.6	138	129	129	17.9	2.56	20.46	2.38	
Eight hours at 8,000 I. H. P.	83.3	150	144	144	17.75	1.94	19.69	2.39	

TABLE V.—*H. M. S. Hermes—Results of water-consumption trials.*

[Made in May and June, 1899.]

Description of trial.	Percentage of full power.	Steam pressure.			Pounds of water per I. H. P. per hour.			Pounds of coal per I. H. P. per hour.	Remarks.
		Boilers.	Engines, starboard.	Engines, port.	Main engines.	Auxiliary.	All purposes.		
Twelve hours at 1,000 I. H. P.	10.0	241	169	176	21.9	5.2	27.1	2.5	Main links linked up as far as practicable. Cut-off in H. P. cylinder 13.5 per cent.
Twelve hours at 1,000 I. H. P.	10.0	163	124	123	20.1	6.67	26.8	2.3	Main links in full gear; independent links run in. Cut-off in H. P. cylinders 47.8 per cent.
Thirty hours at 2,000 I. H. P.	20.0	196	126	127	17.06	4.22	21.28	1.76	
Thirty hours at 7,500 I. H. P.	75.0	263	223	222	15.3	2.1	17.4	1.57	
Twelve hours at 7,500 I. H. P. (Closed exhaust system in use.)	75.0	264	228	219	......	......	16.84	1.5	Auxiliary exhaust at 26 pounds pressure in use on evaporators and surplus to L. P. receivers.
Eight hours at 9,000 I. H. P. (Closed exhaust system in use.)	90.0	270	249	244	......	......	17.13	1.54	Auxiliary exhaust at 29 pounds pressure in use on L. P. receivers only.
Eight hours at 10,000 I. H. P.	100.0	240	231	228	15.64	2.05	17.69	1.58	

TABLE VI.—*Particulars of tubes renewed in Belleville boilers.*

Name of ship.	Total number of tubes fitted.		Generators.	Economizers.	Downcast.
	Generator.	Economizer.			
Sharpshooter	1,080	Nil.	6 tubes (defective)		Nil.
Hermes	2,268	1,944	A number of tubes defective and now being renewed. The following have been ordered and sent to Bermuda: 54 elements, 460 tubes	18 elements	
Terrible	7,200	Nil.	7 elements, 78 tubes		5 tubes.
Diadem	3,332	2,576	8 tubes (defective)	5 tubes (defective).	Nil.
Furious	2,880	Nil.	6 tubes (defective)		Nil.
Europa	3,332	2,576	1 tube (defective)	Nil	Nil.
Arrogant	2,880	Nil.	35 tubes (defective)		Nil.
Powerful	7,200	Nil.	11 elements, 35 tubes		20 tubes.
Niobe	3,332	2,576	1 tube (defective)	Nil	Nil.
Andromeda	3,332	2,576	Nil	Nil	Nil.
Highflyer	2,268	1,944	Nil	Nil	Nil.
Vindictive	2,880	Nil.	Nil	Nil	Nil.
Gladiator	2,880	Nil.	Nil	Nil	Nil.
Argonaut	3,192	4,560	Nil	Nil	Nil.
Goliath	2,450	2,600	Nil	Nil	Nil.
Canopus	2,450	2,600	Nil	Nil	Nil.
Ocean	2,450	2,600	Nil	Nil	Nil.

NOTE.—An element consists of 14 or 20 tubes in the generators and from 12 to 20 in economizers, but in many cases a whole element is removed for convenience when only one or two tubes are defective.

TABLE VII.—*Total number of Belleville boiler tubes (excluding Hermes) which have failed since the accident in the Terrible in March, 1899.*

Name of ship.	Generator tubes.	Economizer tubes.	Downcast tubes.	Total.
Powerful	7	Nil.	10	17
Terrible	Nil.	Nil.	Nil.	Nil.
Diadem	8	5	Nil.	13
Furious	3	Nil.	Nil.	3
Arrogant	4	Nil.	Nil.	4
Europa	1	Nil.	Nil.	1
Total	23	5	10	38

Excluding *Hermes*, there have been only 38 tubes renewed in the whole fleet since the accident in the *Terrible* of March, 1899. Of these 10 were downcomer tubes. Their decay is attributed to defective design. Thirteen were the pitted tubes in the *Diadem* and 9 were due to defective material, namely, 5 lap-welded tubes and 4 solid drawn of the earliest manufacture.

As a result of the *Minerva* and *Highflyer* trials, trials of boilers with small tubes are being urged. A comparison of small-tube boilers in nine ships with those of the *Pearl* class is given in Table VIII, taken from Sir Albert John Durston's article on "Recent trials of the machinery of warships." Table IX, compiled from the tables of the same article, gives the averaged results of boilers of different types and periods.

TABLE VIII.—THIRD-CLASS CRUISERS.

Name of ship.	Description of engines.	Number and type of boiler.	Diameters and ratios of cylinders.	Stroke.	Mean results of trials.			
					Revolutions.	Piston speed (feet per minute).	Steam pressure.	
							Boilers.	Engines.
				Ft. In.				
Pearl class	Vertical, 3-cylinder, triple-expansion.	4 double-ended; 4 furnace.	30½ in., 45 in., 68 in., 1:2.17: 4.97.	2 9	141	775.5	151	146
					160	880	151	146
Pactolus	Vertical, 3-cylinder, triple-expansion.	8 Blechynden.	20½ in., 33 in., 54 in. 1:2.59: 6.93.	2 3	172.8	777.6	224	206
					197.7	889.6	257	248
					213.8	962.1	253	247
Pegasus	do	8 Reed	do	2 3	176.4	793.8	261	237
					203.2	914.4	278	239
					217.7	979.6	255	220
Pelorus	do	8 Normand.	do	2 3	162.1	729.4	249	197
					188.8	849.6	252	200
					217.2	977.4	260	223
Perseus[1]	do	8 Thornycroft.	do	2 3	174.1	783.4	224	211
					195.8	881.1	251	231
					[2]220	[2]990	[2]300	[2]250
Pomone[4]	do	8 Blechynden.	do	2 3	175.6	709.2	247	244
					200.9	904	225	219
					220.3	991.6	252	243
Proserpine	do	8 Thornycroft.	do	2 3	168.7	759.1	232	210
					194.2	873.9	257	243
					221.6	997.2	260	247
Prometheus[7]	do	do	do	2 3	......	......	......	......
					......	......	......	......
					[5]220	[5]990.5	[5]300	[5]250
Psyche[4]	do	do	do	2 3	170.7	768.4	215	215
					......	......	......	......
					217.8	980.1	240	235
Pyramus[7]	do	8 Reed	do	2 3	......	......	......	......
					......	......	......	......
					[5]220	[5]990	[5]300	[5]250
Average for 30 hours at 3,500 H. P.[8]					171.5	771.7	236	217
Average for 8 hours at 5,000 H. P.					[9]196.8	[9]885.4	[9]253	[9]230
Average for 4 hours at full power[10]					218.1	981.3	253	236

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[1] Full-power trial has not yet taken place.

[2] Particulars for full power are from specification.

[3] Calculated from specified I. H. P.

[4] Mean results of Pomone's and Psyche's trials are based on preliminary reports only.

[5] Particulars are from specification.

[6] Calculated from specified particulars.

Table VIII.—THIRD-CLASS CRUISERS.

Mean results of trials.				Weights.		Surfaces.		I. H. P. per ton (mean I. H. P.).		Weight in pounds per I. H. P. (mean I. H. P.).			I. H. P. per square foot of grate (mean I. H. P.).	Heating surface per I. H. P. (mean I. H. P.).
I. H. P. developed (mean).	Duration (hours).	Air pressure (inches).	Coal per I. H. P. per hour (pounds).	Machinery, complete.	Boilers, complete.	Grate (square feet).	Heating (square feet).	Machinery.	Boilers.	Engines.	Boilers.	Total.		
5,016	8	.2	....	539	314	410	11,025	9.3	16	100	140	240	12.2	2.1
7,469	4	1.4	....	539	314	410	11,025	13.8	23.8	68	94	162	18.2	1.47
3,631	30	1.18	2.46	383	188	349.7	17,504	9.48	19.41	121	115	236	10.41	4.82
5,428	8	1.11	Not taken.					14.15	28.91	82.5	75.5	158	15.52	3.22
7,201	4	3.3		....	....	....	....	18.78	38.36	60.5	58.5	119	20.59	2.43
3,698	30	.4	1.96	378	185	360	18,876	9.78	19.98	117	112	229	10.27	5.1
5,400	8	.86	Not taken.					14.28	29.15	80	77	157	15	3.49
7,127	4	2.44		....	....	....	....	18.85	38.48	61	58	119	19.79	2.64
3,559	30	.78	2.2	382	169	350	15,856	9.34	21.06	134.5	106	240	10.16	4.45
5,379	8	1.7	....	....	....	....	....	14.08	31.79	88.5	70.5	159	15.37	2.94
7,094	4	4.3	....	....	....	....	....	18.58	41.92	66.5	58.5	120	20.26	2.23
3,627	30	.3	2.1	365	165	353	17,760	9.93	21.98	123	102	225	10.27	4.89
5,243	8	1.1	2.26	....	....	....	....	14.36	31.77	85.5	70.5	156	14.85	3.38
[3]7,000	[3]4	....	....	....	....	....	....	[3]19,17	[3]42.42	[3]64	[3]58	[3]117	[3]19.83	[3]2.54
3,600	30	.87	2.45	[5]360	[5]170	350	17,504	[6]10	[6]21.19	[6]118	[6]106	[6]224	10.29	4.87
5,541	8	1.4	Not taken.					[6]15.4	[6]32.6	[6]76	[6]69	[6]145	15.8	3.17
7,340	4	2.77		....	....	....	....	[6]20.4	[6]43.15	[6]58	[6]52	[6]110	20.97	2.39
3,644	30	.53	2.4	409	172	348.75	20,508	8.9	21.18	147	105	252	10.47	5.62
5,336	8	.94	2.47	....	....	....	....	13.03	31.04	100	72	172	15.3	3.84
7,145	4	2.9	3.16	....	....	....	....	17.44	41.56	74.5	53.5	128	20.48	2.87
[5]3,500	[5]30	......	....	[5]360	[5]156	353	17,760	[6]9.72	[6]22.43	[6]120	[6]100	[6]230	9.91	5.07
[5]5,000	[5]8	......	....	....	....	....	....	[6]13.88	[6]32.05	[6]91	[6]70	[6]161	14.16	3.55
[5]7,000	[5]4	......	....	....	....	....	....	[6]19.44	[6]44.87	[6]65	[6]50	[6]115	19.83	2.54
3,637	30	.4	2.31	[5]360	[5]165	350	20,508	[6]10.1	[6]22	[6]120	[6]102	[6]222	10.4	5.64
5,095	8	......	2.44	....	....	....	....	[6]14.15	[6]30.9	[6]85	[6]73	[6]158	14.55	4.02
7,006	4	3.7	....	....	....	....	....	[6]19.46	[6]42.46	[6]62	[6]53	[6]115	20.01	2.93
[5]3,500	[5]30	......	....	[5]360	[5]159	360	18,876	[6]9.72	[6]22.01	[6]128	[6]102	[6]230	9.72	5.39
[5]5,000	[5]8	......	....	....	....	....	....	[6]13.88	[6]31.44	[6]89	[6]72	[6]161	13.9	3.77
[5]7,000	[5]4	......	....	....	....	....	....	[6]19.44	[6]44.02	[6]64	[6]51	[6]115	19.44	2.69
3,628	30	.64	2.27	383	176	352.3	18,100	9.65	20.95	126	107	233	10.32	5.06
[9]5,388	[9]8	[9]1.18	[9]2.36	383	176	....	....	[8]14.21	[8]30.88	[8]85.4	[8]72.6	[8]158	15.2	[8]3.44
7,152	4	3.23	....	388	178	....	....	18.92	40.99	63.5	54.5	118	20.35	2.58

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[7] Vessel not yet tried.

[8] Average for seven ships.

[9] Average for six ships; coal per I. H. P. for three ships only.

[10] Average for six ships.

TABLE IX.

Name of ship.	Description of engines.	Number and type of boilers.	Diameter of cylinders and ratios.	Stroke.		Mean results of trials.			
						Revolutions.	Piston speed (feet per min).	Steam pressure.	
								Boilers.	Engines.
Battleships.				*Ft.*	*In.*				
Eight vessels built under naval-defense act.	Vertical inverted tri-compound, 3 cylinders.	8-cylindrical single ended.	40 in., 59 in., 88 in. 1:2.2: 4.8.	4	3	103.1 96.8	876 823	149 150	146 147
Magnificent (10 vessels).	.....do......	.....do........	.....do.........	4	3	103 97.3 83.8	875 827 712	149 148 140	145 144 138
Canopus (6 vessels)	.....do......	20 Belleville, with economizers.	30 in., 49 in., 80 in. 1:2.7: 7.1.	4	3	108	918	300	250
Formidable and Bulwark.	.....do......	.....do........	31½ in., 51½ in., 84 in. 1:2.7:7.1.	4	3	108	918	300	250
Cruisers, first class.									
Terrible, Powerful.	Vertical triple-expansion, 4-cylinder, 4-crank.	48 Belleville, without economizers.	45 in., 70 in., 2 of 76 in. 1: 2.4:5.7.	4	0	65.8 102.75 109.2 113.2	526.4 822 873.6 905.6	216.5 227.5 231.0 243	171 197.5 196.5 202
Andromeda (4 vessels).	.....do......	30 Belleville, with economizers.	34 in., 55½ in., 2 of 64 in. 1:2.66:7.08.	4	0	67.9 106.5 116.6	543.8 852 933.2	218.5 267 286.5	160.5 230 236.7
Edgar class........	Vertical triple-expansion, 3-cylinder.	Return tube; five have 4 double-ended and 1 single-ended; four have 8 single-ended.	40 in., 59 in., 88 in. 1: 2.17:4.84.	4	3	99.1 102.7	842.3 923	150 146.2	146.6 143
Cruisers, second class.									
Diana class (9 vessels.	Twin-screw vertical, 3-cylinder, triple-expansion.	8 3-furnace, cylindrical single-ended return-tube.	33 in., 49 in., 74 in, · 1: 2.2:5.0.	3	3	141.2 135.4 116.4	937.3 880.1 756.6	151 150 142	147 147 139
Apollo and Astræa classes.	Vertical, 3-cylinder, triple-expansion.	Return-tube..	....	3	3	130.8 140	850.2 910	145.0 147.0	141 142.5
Arrogant class (4 vessels).	Twin screw 3-cylinder, triple-expansion.	18 Belleville, without economizers.	26 in., 42 in., 68 in.	3	3	139.5 126.2 85.09	906.4 820.4 553.1	265.5 255.7 220.3	241.4 224.6 182

The *Canopus*, *Formidable*, and *Bulwark* classes have not had their trials. The data is, therefore, calculated from specified particulars. In the *Apollo* and *Astræa* classes 19 vessels have cylinders 33½ inches, 49 inches, and 74 inches; ratios, 1:2.18:4.88. The remainder have cylinders 33 inches, 49

TABLE IX.

Mean results of trials.				Weights.		Surfaces.		I. H. P. per ton (mean I. H. P.).		Weight in pounds per I. H. P. (mean I. H. P.).			I. H. P. per square foot of grate (mean I. H. P.).	Heating surface per I. H. P. (mean I. H. P.).
I. H. P. developed (mean).	Duration (hours).	Air pressure (inches).	Coal per I. H. P. per hour (pounds).	Machinery complete (tons).	Boilers complete (tons).	Grate (sq. ft).	Heating (sq. ft).	Machinery complete.	Boilers complete.	Engines.	Boilers.	Total.		
11,500	4	0.80	....	1,163	595	731	20,438	10	19.7	113	116	227	16	1.7
9,430	8	0.30	....					8.1	15.8	146	141	287	12.9	2.1
12,414	4	0.85	2.40	1,341	724	817	25,233	9.3	17.1	111	131	242	15.2	2.0
10,404	8	0.27	2.25					7.8	14.4	132	156	288	12.7	2.4
6,170	30	Nil.	1.77					4.6	8.5	225	261	486	7.5	4.1
13,500	8	......	....	1,290	623	1,050	33,770	10.5	21.7	111	103	214	12.9	2.5
10,350	30	......	....					8	16.6	144	135	279	9.8	3.3
15,000	8	......	....	1,400	675	1,170	37,120	10.7	22.2	108	101	209	12.8	2.5
11,500	30	......	....					8.2	17	142	131	273	9.8	3.2
5,058	30	0.25	2.18	2,230	1,156	....	....	....	....	....	....	....	....	......
18,479	30	0.36	1.77			2,200	67,800	8.29	16	130	140	270	8.39	3.66
22,547	4	0.34	1.96			2,200	67,800	10.10	19.49	107	115	222	10.24	3
25,774	4	.325	2.11			2,200	67,800	11.55	22.28	94	100	194	11.71	2.63
3,339	30	0.255	2.04	1,540	767	....	....	....	....	....	....	....	....	......
12,785	30	0.287	1.71			1,460	40,990	8.30	16.66	135	135	270	8.75	3.20
16,961	8	0.305	1.73			1,460	40,990	11.01	22.11	103	101	204	11.60	2.41
10,517	8	0.2	1.70	1,161	646	812	24,908	9	16.2	111	138	249	12.9	2.3
12,851	4	0.7	....	1,161	646	812	24,908	11.1	20.1	91	111	202	15.2	1.9
9,846.7	4	1.06	....	915	548	623.8	18,579	10.76	17.97	84	124	208	15.79	1.88
8,307.3	8	0.38	2.18	......	......	....	....	9.07	15.16	99	148	247	13.32	2.23
4,901	30	Nil.	1.64	......	......	....	....	5.35	8.95	168	250	419	7.86	3.78
7,423	8	0.3	....	748	434.4	575	15,641	9.92	17.0	94	132	226	12.9	2.1
9,271	4	1	....	748	434.4	575	15,641	12.40	21.3	76	105	181	16.1	1.7
10,240	8	0.06	....	825	463	869.4	25,606	12.34	22.48	82	99	181	11.82	2.49
7,275	30	Nil.	2.00	......	......	869.4	25,606	8.76	15.95	116	141	257	8.39	3.52
2,186	30	Nil.	2.37	......	......	289.8	8,535	....	....	....	....	....	....	......

inches, and 74 inches; ratios, 1:2.25:5.03. Twenty-one have three double-ended and two single-ended boilers, and eight vessels have eight single-ended return-tube boilers.

The following extract from *L'Eclair*, March 29, 1900, upon these trials will be found interesting:

One of the principal difficulties to be solved in the navy is that of endowing the ships with the best boilers. All the maritime powers have been endeavoring for a number of years to find the type of boiler which will meet all the requirements of economy, power, and security, but the problem has remained unsettled, and the solution has not yet appeared.

Our readers may, perhaps, remember that the Eclair has several times urged that comparative trials be made with the different systems in use in the French navy, in order to note the results obtained and draw from them useful lessons. We have asked that trials be made with three ships of the same power and tonnage, the *Bugeaud*, the *Friant*, and the *Chasseloup-Laubat*, which exactly meet the conditions.

These experiments, which meanwhile would have been very instructive, have never taken place among us, but the English Admiralty has just effected similar trials, which are very much talked of at this moment in the maritime world. Although less complete, less conclusive than those which we have desired, they are not less interesting.

THE SYSTEMS TRIED.

The comparative trials which took place in England were made with the cruisers *Minerva* and *Highflyer*, of 5,600 tons each. The first of these ships, fitted with cylindrical boilers, developed 9,000 H. P., and attained a maximum speed of 19½ knots. The second has water-tube boilers of the type adopted by the British navy for all their new ships. Her horsepower is 9,000 and her maximum speed 20½ knots.

The object of the trials was to determine the advantages and disadvantages of the two types, and the results obtained were to enable a definite decision to be made as to whether cylindrical boilers were preferable to multitublar ones, or vice versa.

Attention should, however, be called to the fact that under the conditions prescribed these trials did not in any definite manner solve the problem proposed; being insufficiently complete, they merely permitted a parallel to be established between cylindrical boilers and the water-tube generators established by the Admiralty. No definite conclusion can be drawn from them as to the respective value of water-tube boilers in general and cylindrical boilers. More extensive experiments, such as those requested by us, would alone permit of a definite comparison.

However that may be, the trials that have just been made by our neighbors are, nevertheless, very interesting.

It is interesting to note, first of all, that, in the trial at full speed, the coal consumption per horsepower and per hour amounted, for the *Highflyer*, to 1 kilo 141 grams, while in the acceptance trials, under the same conditions, the consumption was only 638 grams.

Hence, in practice the consumption of coal per horsepower and per hour for the boilers of this cruiser was almost double that during the acceptance trials. These results prove how little confidence can be placed in the latter trials which everybody, contractors and Admiralty alike, are always interested in showing forth as excellent.

This series of experiments, therefore, gives the advantage to cylindrical boilers, showing less consumption of coal, greater regularity of action, less inertness of apparatus, and greater promptness in restoration to a condition of service. Nevertheless they do not suffice as yet for a conclusion that the cylindrical boiler is superior to the water-tube boiler. Only one thing can be affirmed, which is that it is preferable to the multitublar type adopted by the English Admiralty with which it has been compared.

It is not to be denied that the water-tube boiler, as compared with cylindrical boilers, shows military advantages upon which its use on war ships rests, but it should be known how to choose among the types employed, and that is why we demanded in 1896 and 1898, as we still demand to-day, that earnest experiments be made with the different types actually in service. Let us imitate our neighbors, but let us extend the scope of our experiments. Let us not forget that the boiler is the soul of the ship.

At the same time that the trials of which we have just spoken were being conducted the English Admiralty arrived at another equally interesting decision. It decreed that in the future no multitubular boilers should be accepted having tubes of less than 75 to 82 millimeters diameter.

This determination is the more singular since all water-tube boilers of English origin are of the same type and have tubes of small diameter. The English have recognized in these different models a grave inconvenience, which we have also observed in France, which is that these tubes are difficult to examine, clean, and repair; so much so that boilers of this model can hardly undergo a service of twelve or fifteen hundred hours of heating without it being necessary to change almost the whole tubular system.

In France we have gone further than our neighbors in the use of boilers with small tubes. In England their use has been limited to the smaller vessels, but we have placed them upon certain of our ships of heavy tonnage, such as the *Jeanne d'Arc*, the *Montcalm*, the *Chateaurenault*, etc. We have gone so far in this direction that the power represented by apparatus of this kind at the present time amounts to more than 250,000 horsepower. We should show proof of wisdom if, like our neighbors, we would take the trouble to assure ourselves in advance of the comparative value of the implements of warfare which modern inventions place at our disposition.

A writer in the *Marine Française* makes the following comments upon the economizers and their injurious influence in the case of boilers of the type used by the *Highflyer;* that owing to the difficulty of finding space in ships of war for the economizer several of the upper rows of tubes of the boiler have to be taken away, thus considerably reducing its heating surface; and that, because the tubes of the economizer, through which flows water of a relatively low temperature, have a tendency to become fouled, as happened to the battleships *Charlemagne* and *Gaulois* in their voyage from Brest to Toulon, when the economizer tubes were, after their arrival, found to be fouled with a coating 3 or 4 millimeters thick, thus preventing the full use of heat. The results of the *Minerva-Highflyer* trials are summed up as follows:

1. That the water-tube boilers of the *Highflyer* consumed more fuel at all speeds than those of the *Minerva*, the difference at low speeds amounting to 27 per cent.
2. The coal consumption of the *Highflyer* was practically double what it had been at the delivery trial, making a considerable reduction of the radius of action.
3. That the economizers are not only useless, but are prejudicial after working for a certain length of time; and are, besides, objectionable in a military point of view, owing to their exposed position.
4. That the water-tube system adopted by the Admiralty is defective in the sense that a vessel is immobilized for a relatively long period after each period of steaming, in order that the tubes may be cleaned and repaired.

THE SEAGULL'S TRIALS.

In the last annual there appeared an article upon the trials of the *Seagull* (Niclausse boilers), *Sharpshooter* (Belleville boilers; no economizers), and the *Shelldrake* (Babcock-Wilcox boilers), and as the *Seagull* had not at that time finished her trials the following information is given to complete the comparison of the different types:

The *Seagull*, a torpedo gunboat of 735 tons displacement, is the only vessel in the English navy fitted with Niclausse boilers. The great advantage claimed for this boiler is the facility with which the tubes can be removed and replaced. The tubes are straight and of 3¼ inches diameter.

The *Seagull*, whose maximum horsepower is 3,000, was to make nine trials of 1,000 miles each—four at 1,350 horsepower, two at 1,600, two at 1,780, and one at 1,900; but she only used four of her six boilers, and consequently the actual power at the time of the last trial was nineteen-twentieths of the maximum for the boilers in use.

The mean of the nine runs gave a coal consumption for the main engines of 1.9 pounds per horsepower per hour, and 2 pounds for all purposes.

In four of the runs the *Seagull* did not complete the 1,000 miles, owing to bad weather. In the first four trials the I. H. P. ranged from 1,354 to 1,371, and the speed varied from 13 to 13.6 knots. The fifth trial gave a speed of 14.48 knots with 1,611 I. H. P., and the sixth, with 1,631 I. H. P., increased the speed to 14.6 knots. The seventh trial was carried on in bad weather and had to be abandoned when 855 miles had been run; but with 1,798 I. H. P. the *Seagull* averaged 15.2 knots. The eighth trial was run in fine weather and the 1,000 miles completed, when a speed of 15.4 knots was made with 1,800 I. H. P. On the ninth trial a speed of 16.07 knots was made, with 1,947 I. H. P.

According to the accounts in the press, what impressed the English officers and engineers most was the facility with which a tube could be replaced. The experiment was made, and according to reports, in twenty-five minutes the fires of one of the boilers were banked, a tube was exchanged, and steam was once more got up. It was also ascertained that steam can be obtained very rapidly—in about ten minutes; that one can pass from one rate of speed to another in a few seconds, and always produce extremely dry steam.

No accidents occurred during these trials and the boilers were tended by the ship's force.

The system of using water-tube boilers in the German navy differs to some extent from that customary in the navies of the other principal powers. This system is described in the following article translated from *Internationale Revue ü. d. ges. Armeen und Flotten, May, 1900*, which also shows the methods adopted in their most recent ships:

THE QUESTION OF WATER-TUBE BOILERS IN THE GERMAN NAVY.

Referring to the article on page 62 of the January number of this magazine, treating generally of the question of water-tube boilers used by the principal sea powers, the following pages will speak more particularly of this question as far as the German navy is concerned:

As to the types of boilers adopted by the German navy, both the home and the foreign press have recently made frequent statements, which, in many respects, can not lay claim to accuracy. In most cases it has been definitely stated that a certain type was preferable to all others, an assertion which should not be made without reservation.

The annexed table (Table X) shows the different types of boilers which have been used on board the larger ships of the German navy.

By comparing the respective years of construction, it will be seen that at first water-tube boilers with large tubes of from 80 to 100 millimeters diameter, such as the *Belleville*, *Niclausse*, *Dürr*, etc., were in favor, but that very soon water-tube boilers with small tubes, of from 29 to 36 millimeters diameter, were given preference. Although last year the large-tube boiler systems, owing to their satisfactory qualities in other respects, were frequently used for new ships of the German navy, they appear now to come into disuse. The reasons therefor seem to be their great weight, the extravagant coal consumption, and the large amount of smoke developed as a result, the length of time it takes to clean them, and the absolute necessity of frequent cleaning in order to obviate disturbances in the operation, and finally, the great sensitiveness of the types referred to even to small quantities of salt in the feed water. For instance, for one of the large-tube boiler types mentioned above, it takes a whole week to take it apart, clean it, and mount it again—and that, when such work is done by skillful and experienced hands. For this purpose, from 300 to 400 covers have to be unscrewed and passed between the close series of stay-bolts in the water chamber, and the same number of tubes have to be pulled out forward. The cleaning itself is equally laborious and requires a great deal of time, and so does the putting together. Another drawback of these boilers is the fact that even a very small amount of salt in the water causes them to foam, and the strong water shock in the tubing, and especially the water entering the steam cylinders, endangers the whole engine installation to such an extent that it may disable it altogether. Hence, a ship equipped with this type of boilers may be crippled even by small leakages in the condenser tubes.

Of the small-tube water-tube boilers, only the Thornycroft and Schulz boilers need be considered at the present time, because these two systems, with economic coal consumption, develop a minimum of smoke and have the further advantage of small weight; they can, moreover, be easily and rapidly cleaned, steam can be got up quickly, and the maximum speed attained in a short time.

The table further shows that on board the large cruisers and battleships of the German navy, the whole boiler installation is not always of one and the same system. On the contrary, in large installations, with engine powers of from 13,000 to 25,000 I. H. P., only a part (one-third to one-half) of the boilers are of the water-tube type, while the others are cylindrical boilers of the systems hitherto employed. For instance—

H. M. S. *Kaiser Friedrich III* has two-thirds cylindrical and one-third water-tube boilers (partly Schulz and partly Thornycroft system).

H. M. S. *Kaiser Wilhelm II* has one-half cylindrical and one-half Schulz boilers.

H. M. S. *Kaiser Karl der Grosse* has one-half cylindrical and one-half Schulz boilers.

Battleships "A" and "D" are to have one-half cylindrical and one-half Thornycroft boilers; battleships "C," "E," "F," and "G," one-half cylindrical and one-half Schulz boilers.

H. M. S. *Fürst Bismarck* has two-thirds cylindrical and one-third Schulz boilers.

It will be seen from the above that in the so-called combination systems, the Schulz and Thornycroft are the only types of water-tube boilers employed.

For small cruisers with engines of 8,000 I. H. P., the boiler installations consist exclusively of water-tube boilers of a single type. This is also the case with regard to the new gunboats *Jaguar*, *Tiger*, and *Luchs*. As the table does not include these smaller vessels, it may be added that they have been equipped with Thornycroft boilers.

TABLE X.—THE WATER-TUBE BOILER

			Boilers with large tubes.				
	Displacement.	Total I. H. P.	System.	Firm of construction.	When built.	Efficiency.	Heating surface in square meters.
Battleships:							
Siegfried class—							
Aegier	3,600	5,000					
Hagen	3,600	5,000					
Sachsen class—							
Baden	7,440	6,000	Germania.	Germania	1895–1897	6,000	1,680
Bayern	7,440	6,000	Schichau	Schichau	1896–1897	6,000	2,000
Sachsen	7,440	6,000	Durr	Durr	1897–1899	6,000	1,600
Württemberg	7,440	7,000					
Line of battleships:							
Kaiser Frederich III	11,180	13,000					
Kaiser Wilhelm II	11,180	13,000					
Kaiser Wilhelm d. Grosse	11,180	13,000					
Kaiser Barbarossa	12,000	15,000					
Kaiser Karl der Grosse	12,000	15,000					
C	12,000	15,000					
D	12,000	15,000					
E	12,000	15,000					
F	12,000	15,000					
G	12,000	15,000					
Armored cruisers:							
Fürst Bismarck	10,650	15,000					
Prinz Heinrich	8,870	15,000	Durr	Durr	Building	15,000	3,700
B	8,870	15,000	do	do	do	15,000	3,700
Large cruisers:							
Hansa	5,900	10,000	Belleville.	Vulcan	1896–1897	10,000	2,200
Victoria Luise	5,900	10,000	Durr	Durr-Weser	1896–1898	10,000	2,500
Vineta	5,900	10,000	do	Durr f. K. Werft Danzing.	1897–1899	10,000	2,300
Freya	5,900	10,000	Niclausse.	Niclausse Germania, f. K. W. Danzing.	1896–1899	10,000	2,400
Hertha	5,900	10,000	Belleville.	Vulkan	1896–1898	10,000	2,200
Small cruisers:							
Gazelle	2,700	6,500	Niclausse.	Niclausse Germania.	1896–1898	6,500	1,440
Nymphe	2,700	8,000					
Niobe	2,700	8,000					
C	2,700	8,000					
D	2,700	8,000					
E	2,700	8,000					
F	2,700	8,000					

INSTALLATIONS OF THE GERMAN NAVY.

	Boilers with small tubes.							
	Thornycroft system.				Schulz system.			
In connection with fire-tube boilers.	Firm of construction.	When built.	Efficiency.	Heating surface in square meters.	Firm of construction.	When built.	Efficiency.	Heating surface in square meters.
......	Oderwerke..	1895...	5,000	1,480	......	......	......	......
......	.....do......	1899...	5,000	1,480	......	......	......	......
......	......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......	......
......	......	......	......	......	Germania.........	1898-1899..	7,000	2,000
Water-tube boilers:								
One-third of whole.	......	......	......	......	......	......	......	......
.....do	......	......	......	......	Germania.........	1898-1899..	5,200	1,400
One-half of whole..	......	......	......	......	.....do............	Bldg. 1899.	8,200	2,100
.....do	Schichau...	Bldg..	8,500	2,200	......	......	......	......
.....do	......	......	......	......	Blohm-Voss.......	Building .	8,200	2,100
.....do	......	......	......	......	K. W. Wilh........	.....do....	8,800	2,300
.....do	Schichau...	Bldg..	8,800	2,300	......	......	......	......
.....do	......	......	......	......	Germania.........	Building .	8,800	2,300
.....do	......	......	......	......	Vulkan	......	8,800	2,300
......	......	......	......	......	K. W. Wilh........	Building .	8,800	2,300
One-third of whole.	......	......	......	......	Germania.........	1898-1899..	5,600	1,500
......	......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......	......
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......	......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......	......
......	......	......	......	......	Germania.........	Bldg. 1898.	8,000	2,300
......	Weser	1899...	7,000	2,300	......	......	......	......
......	......	......	......	......	K. W. Danzing	Bldg. 1898.	8,000	2,400
......	......	......	......	......	Weser.............	.....do....	8,000	2,400
......	......	......	......	......	.....do............	.....do....	8,000	2,400
......	......	......	......	......	Germania.........	.....do....	8,000	2,400

Kaiser Frederich III, Thornycroft and Schulz systems combined, built by Oder works; year of construction, 1898; efficiency, 5,200 I. H. P.; heating surface, 1,400 square meters.

The following table will show the extent to which the different types of boilers have found application in the German navy:

	Number of boiler installations.	Efficiency in I. H. P.	Heating surface in square meters.
1. Large-tube water-tube boilers:			
(a) Dürr (including Germania and Schichau)	7	68,000	14,480
(b) Niclausse	2	16,500	3,840
(c) Belleville	2	20,000	4,400
2. Small-tube water-tube boilers:			
(a) Thornycroft	5	34,300	9,760
(b) Schulz	14	109,400	30,500

The water-tube boilers of the battleship *Kaiser Friedrich III* have not been included above for the reason that the elements of construction of the Thornycroft and Schulz systems have been intermingled so that one particular type can not be spoken of in this case. Their efficiency, however, is 5,200 I. H. P. with 1,400 square meters heating surface.

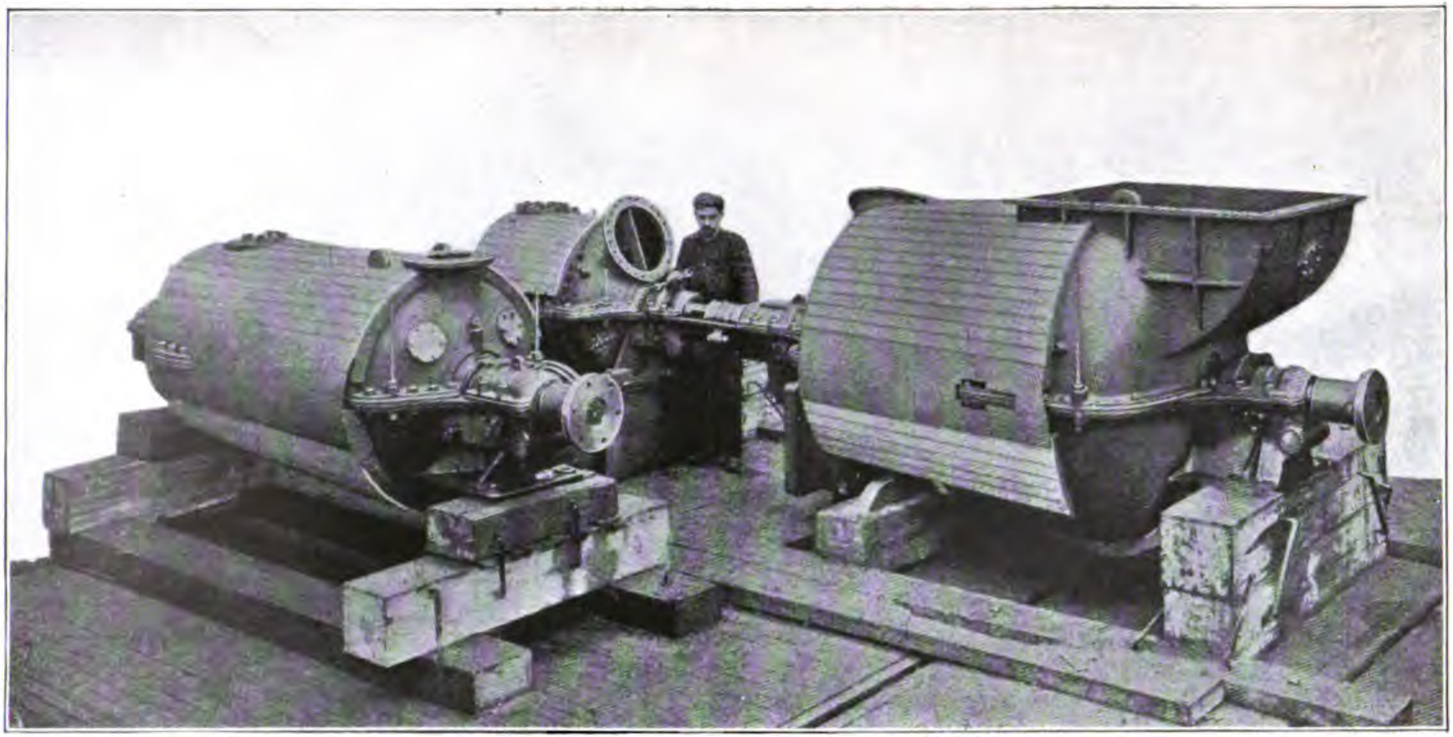
With the exception of Niclausse boilers, all the water-tube boilers that are or have been used in the German navy were constructed at home with German material, namely: The Thornycroft boilers at the Oder Works and at Schichau's; the Schulz boilers at the Germania Yards, the three Imperial Yards, Blohm & Voss, the Weser-Vulkan, and the Oder Works; the Belleville boilers at the Vulkan Works; the Dürr boilers by Dürr & Co.

As already stated, of the small-tube water-tube boilers which have taken the place of the large-tube boilers in the German navy, only the Thornycroft and Schulz boilers need be considered. The main distinction between these two types consists in the manner in which the fire gases are conducted. While in the Thornycroft system the fire gases are conducted vertically, by a single way, from the bottom to the top, through the bundle of tubes, in the Schulz boilers they do not pass by a single way only, horizontally-vertically, but by two or three ways through the different bundles of tubes. The latter method results in a more advantageous utilization of the fire gases and, consequently, a lower temperature in the smoke pipes, so that a development of flames in the smoke pipes is entirely excluded even with maximum forced draft, while this constitutes one of the objections to other boilers. Moreover, the construction is simple and substantial; the boilers can be easily served and all connections are accessible. One advantage, which is common to both types, is the ease with which the boilers can be cleaned; it can be done in a few hours by boiling soda in them.

NEW TYPES.

VIPER.

The *Viper* has just completed some very interesting trials, developing a speed of 34.75 knots. In a preliminary test before this official trial a mean speed of 34.8 knots was obtained in four consecutive runs on the measured mile, the fastest run being at the rate of 35.5 knots. The accompanying cut of her turbines, published by the *Engineer*, shows her high and low pressure turbines and the reversing turbine of one set of engines.



TURBINES OF H. M. DESTROYER VIPER.

The following are the dimensions of the *Viper:* Length, 210 feet; beam, 21 feet; draught, 12 feet 9 inches; displacement, 350 tons. The indicated horsepower is about 11,000. The turbine engines are in duplicate and consist of two distinct sets, one on each side of the vessel. There are four screw shafts in all, independent of one another, the two shafts on one side being driven by one high and one low pressure turbine, respectively. The high-pressure turbines are 35 inches in diameter and the low-pressure turbines 50 inches in diameter. The two low-pressure turbines drive the two inner shafts, and to each of these shafts a small reversing turbine is also permanently coupled and revolves idly with the shaft when going ahead. These reversing turbines provide sufficient power to drive the vessel astern at a speed of 15 knots. Two propellers are placed on each shaft, the foremost in each case having a slightly lesser pitch than the after one. There are thus eight propellers in all. The thrust from the screw shafts is entirely balanced by the steam acting on the turbines, so that there is but little friction.

The engine room is quite different from that usual in the Destroyer type. Upon the platform there are no working parts visible only the large stop valves which control the steam to the turbines. Beneath the platform are placed the turbines and the condensers, the latter occupying the larger part of the space.

The *Viper* is fitted with four boilers of the Yarrow straight-tube express type. The boilers, auxiliary machinery, and condensers are of the usual type, but their size is somewhat increased to meet the much larger horsepower to be developed. This compensates for the lesser weight of the main engines, shafting, and propellers, as well as the lighter structure of the engine beds.

The official trial of the *Viper* was made on the North Sea, off the mouth of the Tyne, on the 4th of May. The displacement on trial was 375 tons, with all coal on board. The contract load was 40 tons, but this was increased to 60 tons. Full steam had not been reached when she entered on the mile, and even on the second run the speed did not quite reach 30 knots. Ten runs were made in all, and taking the best six consecutive runs—with and against the tide—a speed of 34.28 knots was reached. The best two runs gave a mean speed of 34.75 knots, while the mean speed on the three hours' run was 33.96 knots.

The mean revolutions were 1,050 per minute, and the mean steam pressure ranged from 165 to 175 pounds to the square inch. It is stated that a great deal of steam was lost at the relief valves, which had not been sufficiently screwed down before starting, and began to blow heavily soon after going on the mile. The total heating surface in the four Yarrow boilers is 15,000 square feet, and the grate surface is 275.75 square feet. The air pressure for draft averaged 3 inches on the water gauge. The indicated horsepower estimated by the steam pressure and revolutions is taken at 11,000. The trial was carried out under Admiralty conditions.

The absence of vibrations, running at all speeds, is said to be remarkable, so far as the main engines are concerned. There is some noise and vibration due to the auxiliaries, and it is proposed to get rid of this by using electricity to drive the auxiliaries.

COBRA.

The unofficial trials of a torpedo-boat destroyer built by Messrs. Armstrong, Whitworth & Co., supplied with turbine machinery by Messrs. Parsons & Co., and with four Yarrow water-tube boilers by Messrs. Hawthorn, Leslie & Co., have been so satisfactory that the Admiralty has purchased the vessel and named her the *Cobra*. She is 323 feet long by 20 feet 6 inches beam and 13 feet 6 inches deep. She has an estimated horsepower of 12,500, transmitted through four lines of shafting, each fitted with three propellers. The vessel in a series of six runs over the measured mile attained a maximum speed of 35.886 and a mean speed of 34 knots.

GENERAL BAQUEDANO.

This ship possesses some new and very interesting features in the arrangement of her cylinders. The system is shown by the accompanying cut. In an article before the Institution of Naval Architects, Mr. Magnus Sandison has described the features of the design as follows:

(*a*) The production of an engine which will work with economy when developing a small proportion of its full power, and thus insure in a given ship the maximum radius of action.

(*b*) The elimination, as far as possible, of the unbalanced forces in the engine.

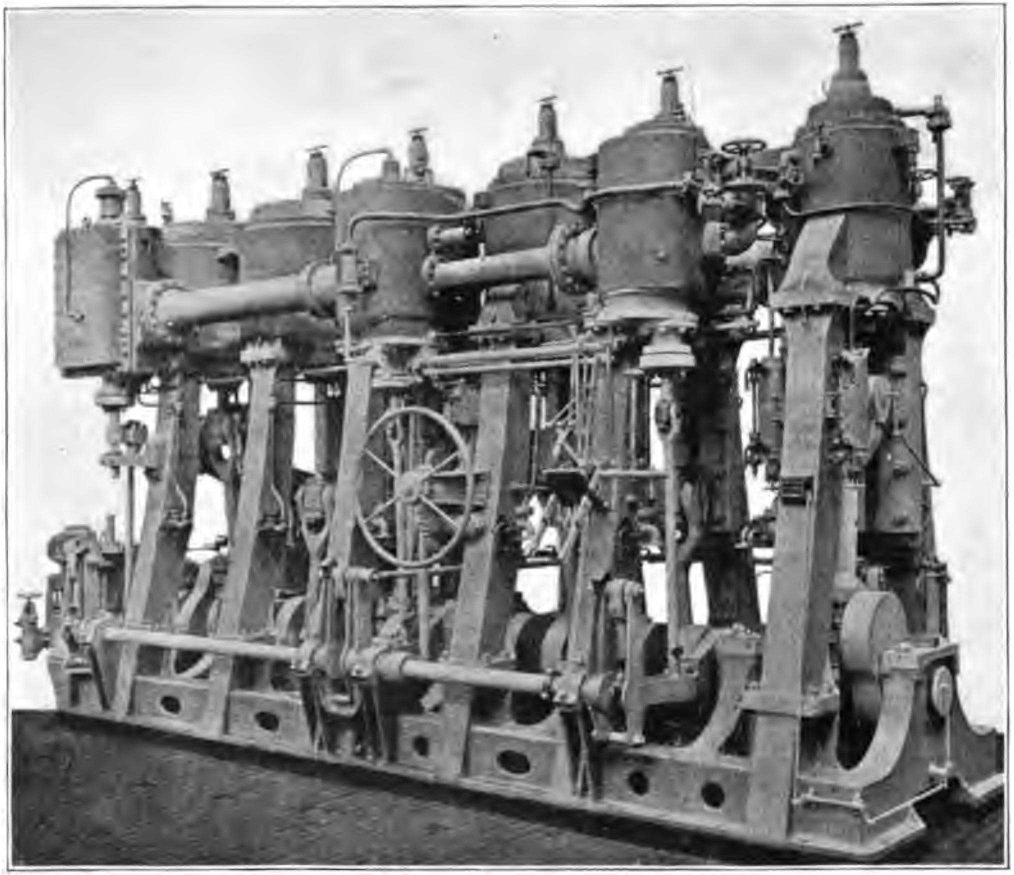
(*c*) The securing, as far as possible, of uniformity in the turning effort on the crank shaft.

(*d*) The reduction to a minimum of the chance of total disablement.

The *General Baquedano* is a full-rigged bark, built for the Chilean navy by Armstrong, Elswick, and launched July 5, 1898. The following are the dimensions: Length between perpendiculars, 240 feet, over all, 277 feet; beam, 45 feet 9 inches; draught, 18 feet; displacement, 2,330 tons. The contract called for 2,500 I. H. P. and a speed of 13 knots, and with open stokeholes, 1,500 I. H. P. and 12 knots. The armament consists of four 4.7-inch R. F. guns, two on each side, two 12-pounder R. F. guns, two 6-pounder R. F., one 1.85-inch R. F., and two Maxim machine guns, besides one 18-inch torpedo tube.

The machinery consists of a single screw engine driving a feathering propeller, steam being supplied by four Belleville boilers, having a steam pressure of 300 pounds, reduced to 250 pounds at the engine.

By disconnecting and securing the bottom ends of the connecting



ENGINES OF THE CHILEAN CORVETTE GENERAL BAQUEDANO.

and valve rods of one set of engines, the other set can still drive the propeller, the cylinders being proportioned so as to do this with an economy attained in the mercantile marine.

The speed trials consisted of a six hours' run at full power, and a thirty hours' run at three-fifths full power. On the full-power trial she made a speed of 13.75 knots with a mean of 154 revolutions. At the conclusion of this trial the turning gear was shipped, and within an hour from that time the vessel was underway again, steaming with one set of cylinders, the bottom ends of the disconnected rods being secured by means provided for the purpose.

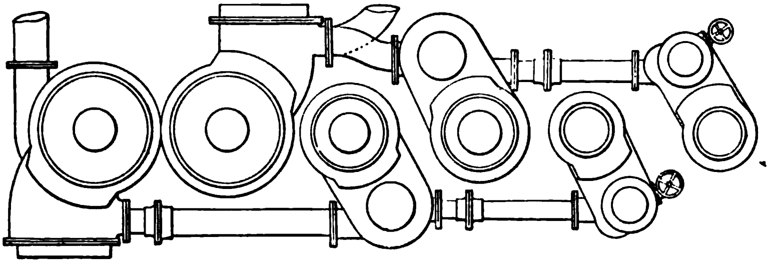


FIG. 3.—Arrangement of cylinders in *General Baquedano.*

It is possible, by reducing the pitch, to develop half power with one set of cylinders working; but with vessels fitted with ordinary screws, with two engines on one shaft, the proportion of power developed would be less.

To counteract any tendency to set fast on the part of the disconnected gear, if disconnected for a long period, the securing gear is so arranged as to permit of a limited motion being given to the various parts. The handling of the engines, whether three or six cylinders are at work, is performed with the same ease as in the ordinary triple-expansion three-cylinder engine, one or both engines being worked by the same regulator and reversing engine. An independent steam cut-off valve is attached directly to each high-pressure cylinder.

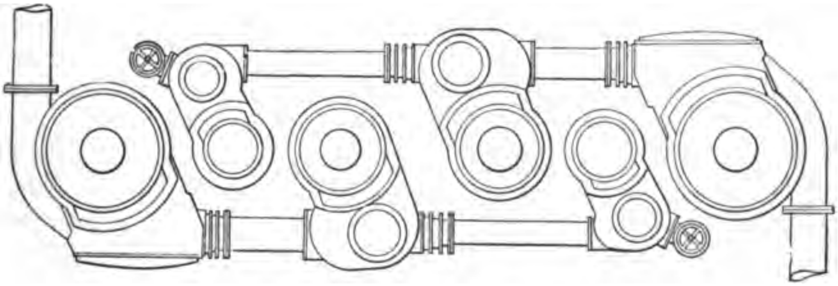


FIG. 4.—Another arrangement, same system.

The piston rods, connecting rods, etc., and their accessories are duplicates throughout, except in the case of two engines designed to develop different powers when working together.

CASUALTIES.

Most of the casualties reported during the year have occurred on board of torpedo boats. On February 21 the destroyer *Bat* was making a full-speed run of one hour duration. Toward the end of the hour, when everything was going well, the engines making 360 revolutions and the boat traveling 28 knots, a loud noise was heard, followed by a rush of steam. Steam was shut off and the engine-room force escaped without injury. The starboard engine was found to be badly damaged and the cause of the accident traced to the cap of the low-pressure crosshead brasses, which had fractured across the bolt holes. This fracture freed the connecting rod, which knocked against and bent the crosshead guide, and made a bulge in the condenser. The piston being free, was forced up and broke the cylinder cover, at the same time cracking the cylinder.

A similar accident to the above occurred on board the destroyer *Bullfinch* on July 21. This vessel had carried out six runs on the measured mile at a required speed of 30 knots. She then steamed as far as Cowes and was entering the Solent when the connecting rod of the high-pressure starboard cylinder broke close to the fork. The piston knocked off the cover and the forepart of the engine room was filled with steam from which none of the engine-room force could escape. The end of the rod was driven through the bottom of the vessel, which began to leak badly. The commanding officer quickly put over collision mats, which checked the rush of water. Unfortunately eleven lives were lost by this accident.

On May 8 the destroyer *Recruit* had a serious accident. During her steam trials the studs on the low pressure eccentric straps carried away, and the balance piston knocked out the end of the balance piston cylinder. No lives were lost.

On board the French battleship *Massena*, while four engineer officers were dismounting an escape pipe in order to clean it, by accident they disjointed the parts too quickly; steam concentrated in the escape pipes, and escaping by numerous joints, scalded the men badly.

In February, when the French squadron was getting underway, an explosion in one of the boiler rooms of the armed crusier *Chanzy* burned several men, one of whom died.

Two serious accidents have occurred on board French torpedo boats *No. 228* and *No. 213*.

While *No. 228* was steaming at 25.5 knots, the piston rod broke and knocked off the cylinder cover. Five men were badly burned and one, jumping overboard in his agony, was lost. According to later reports two more have died.

A board was appointed to investigate the accident on board *No. 213* and reported that it was caused by an exterior tube cracking and emptying the boiler without the engineer noticing the fact. The interior tubes then became heated to a white heat, and one exploded, allowing the steam to escape from the steam chest. This steam forced the flames through the ash pits out into the fire room. The fire-room force became panic stricken and endeavored to save themselves, opening the hatch leading above. This was their ruin, for the flames, drawn by this new draft, filled the fire room. The engineer has since died from the effects of his burns.

An explosion occurred recently on board of a Turkish torpedo boat. The boat sank and the lives of all persons on board were lost.

A Russian torpedo boat, *No. 38*, of a very old type, had been undergoing repairs and was making some trials when the boiler exploded killing six persons. The men were blown into the air and their bodies found in the water. The boat sank. The explosion did considerable damage to neighboring vessels. The accident was attributed to defective gauges which failed to show the pressure in the boilers.

One of the most distressing accidents occurred on board the Austrian torpedo boat *Adler*, on July 22. This vessel was built by Yarrow and her boilers, which were of the locomotive type, by Hicks & Hargreaves, The boat was steaming at a reduced speed, making from 12 to 14 knots, carrying about 120 pounds of steam. Suddenly there was an explosion, the débris and hot water from the boiler falling on deck. Two of the crew were killed by falling débris, three were blown into the water and lost, and four were injured. It was found that the deck over the boilers was torn up and the boiler, by the reaction of the escaping steam, had blown itself overboard. The mast fell on deck and both stacks were bent. The bulkhead between the boiler room and engine room was broken through. All gear above the boiler room had disappeared. The boiler mountings and stokehole floor plates were blown overboard with the boiler. The boiler had been examined and cleaned two days previous to the accident. The fire-room force were killed, so it was impossible to find out the condition of affairs in the fire room. A sail was rigged and the boat beached, having been about 3 miles from shore when the accident occurred. It is reported that men-of-war made an effort to recover the boiler by dragging, but were unsuccessful.

LIQUID FUEL.

The great advantages to be derived by the use of liquid fuel have caused the principal maritime powers to continue their experiments in its use, both in their navies and merchant marine. For military reasons some of the powers have been less enthusiastic than others, while some have been satisfied to await results.

Russia has been the most energetic and, apparently, the most successful in experimenting with liquid fuel. She is interested beyond the immediate advantages of the success of these experiments, owing to her great supply of oil and scarcity of coal. Its use has increased to such an extent in that country during the last few years as to cause a great rise in price, and the demand is increasing more rapidly than the production.

In an article written by Mr. N. Cherkassov on petroleum fuel for the volunteer fleet and Russian navy, he suggests, owing to the great demand for liquid fuel, that 10 per cent be deducted annually by the Russian Government, by way of impost, to secure a supply for the navy. Owing to the use of this fuel by the steamers on the Caspian (about 200) and those on the Volga (about 1,000), as well as most of the Russian railways and works so situated as to be able to use it, the total consumption has reached 4,840,000 tons per annum.

Mr. Cherkassov gives the following methods for supplying the fleets: "The Black Sea fleet could be supplied by direct pipe lines and the Baltic fleet by depots at suitable places along the Volga, which could be supplied by water carriage from the Caucasus, and from which oil could be supplied to St. Petersburg and to the Baltic ports by rail or water carriage." This would make Russia independent of other countries for fuel supply for her fleet.

The components of the crude petroleum of the Caucasus, generally called raw naphtha, is given as 86.87 per cent carbon, 12.19 per cent hydrogen, 0.87 per cent oxygen, and 0.06 per cent sulphur, besides small quantities of oxide of iron, alumina, lime, copper, and traces of silver and gold. Astaki is the residue remaining (60 to 65 per cent) in the distillation of the crude naphtha after separating from it the kerosene (30 to 35 per cent) and benzine (4 to 5 per cent), and this astaki forms the ordinary liquid fuel.

The great advantages in the use of liquid fuel in the navy are the facility of handling and transportation, absence of smoke, facility of managing the fires, and quickness with which steam can be raised and controlled.

The use of liquid fuel, with its facility of handling and transportation, was often referred to by our officers during the late war as one of the possibilities of the future. The strain upon the officers and men was intense when coaling alongside colliers at sea. Batteries had to be run in on many ships, and in some cases guns dismounted, to clear the colliers. Frequently holes were made in them by the motion of the vessels coaling alongside, and guns were in great danger of being knocked off their carriages and thrown out of action.

Liquid fuel can be supplied with a very high flashing point and can be considered as safe as coal for transportation, the temperature of ignition depending upon the completeness of distillation.

Oiling stations are reported as being erected in the East ranging from Yokohama to Suez, and large oil ships are being prepared for its transportation, thus solving the supply to ships in that direction. The Hamburg-American line is said to have entered into a contract whereby liquid fuel is to be furnished for their vessels at Suez, Colombo, Singapore, Hongkong, and Shanghai, and they are preparing some of their steamers for its use. It is also reported that Lloyds have decided to adopt it, and that the Peninsular and Oriental Steamship Company are investigating it.

The cost of using liquid fuel is greater than coal, both in railways and ships, but the advantages are causing it to be used to a greater extent from year to year. In the Mediterranean, away from the vicinity of the wells, the cost is about twice that of coal. The advantages would outweigh the expense as used for naval purposes.

The United States produces an enormous supply of petroleum, but has not shown such an active interest in its use for maritime purposes as some of the powers, probably owing to her great coal supply. Petroleum has been used as fuel on the locomotives of some railroads in the United States, the crude petroleum, substantially as it comes from the wells, being used. Experiments have also been carried on from time to time in torpedo boats.

In Italy and Austria refuse of petroleum has been used. Italy, owing to her position and deficiency in coal, is peculiarly interested in the use of liquid fuel, and has been very active in experiments for years, although she produces none. She has fitted a great many of her battleships, cruisers, and torpedo boats for its use. Up to the present time it is reported that about twenty battleships and cruisers have been fitted to burn a mixture of petroleum and coal, and about thirty torpedo boats to burn petroleum.

Germany, producing an insufficient supply of petroleum, has carried on experiments with a tar oil, called "mazut," of which she has a greater supply, and has fitted some of her ships for burning liquid fuel and some for burning oil in mixed combustion. The imperial yacht *Hohenzollern* is to have some of her boilers altered to burn oil. The coal bunkers are to retain their former capacities, but part of the ship's double bottom will be used for its storage.

France has carried on many experiments with petroleum as fuel, in her ships rather than in her torpedo boats, the use of petroleum and coal in mixed combustion being the practice. This system is advocated by some of the powers for use instead of forced draft, as being less injurious to the boilers when great speed is suddenly required. In the *Formidable*, recently fitted for burning petroleum in mixed combustion with coal, it is intended to be used only in an emergency. The tanks are built in the bunkers and have a capacity of 50 tons. The petroleum is pulverized by steam, delivered by one burner in each furnace, fitted at the front over the furnace door. The oil is not filtered but is heated to increase its flow and is forced under slight pressure. Her speed is said to have been improved by its use. The *Amiral Baudin* has also been fitted with these burners, and they are reported to have worked satisfactorily on her trials. In addition to the above, the following ships have provision for carrying petroleum: Battleships—*Charlemagne*, *Saint Louis*, *Gaulois*, *Suffren*, *Jéna;* armored cruisers—*Dupetit Thouars*, *Amiral Gueydon*, *Montcalm*, *Jeanne d'Arc*, *Conde*, *Gloire*, *Sully*, *Marseillaise*, *Amiral Aube;* cruisers—*Guichen*, *d'Entrecasteaux*, *Jurien de la Gravière*, *Sfax.*

England has experimented with liquid fuel in the topedo boat *Surly*. These trials have not been entirely satisfactory, owing to the thick black smoke produced. The *Surly* was fitted with the system invented by Mr. Holden, of the Great Eastern Railway. Of the four boilers two were fitted for this system and two retained for coal.

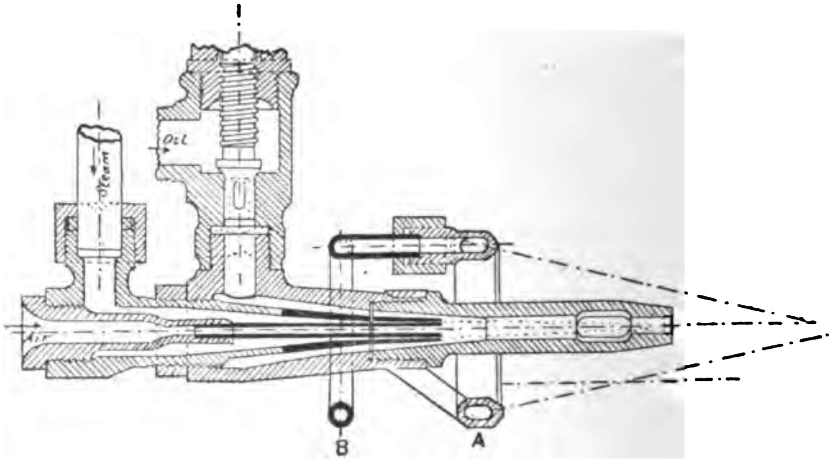


Fig. 1.

Mr. Holden's burner is shown in figure 1. The air is admitted through a central pipe, the steam through an annular space outside it, and the oil through an annular space outside the latter. The peculiarity of this burner lies in the fact that the steam is also admitted to a pipe, A, bent into a ring near the end of the burner, through small holes, and is directed upon the jet of steam and petroleum, which pulverizes it and mixes it with air for combustion. The oil had a flashing point of 280° F. It is reported that the Admirality are not enthusiastic over the liquid fuel problem, owing to the result of the trials in the *Surly* and also to the fact that Russia might have to be their source of supply.

The *Haliotis*, one of the vessels of the Shell Transport and Trading Company, was designed especially for the oil carrying trade and has her furnaces fitted for burning liquid fuel. They can be quickly altered on board for burning coal. The bunkers of the ship are so constructed that they can be used for either oil or coal. From them the oil is pumped to a service tank above the boilers, whence it flows by gravity to a device at the furnace, where, by means of a steam jet, it is pulverized or broken into spray. In the trials it was found that 2.27 pounds of ordinary English coal were used for each indicated horsepower per hour, as compared with 1.67 pounds of oil.

The system for burning liquid fuel applied to the steamship *Cardium*, one of the vessels of the Shell Transport and Trading Company, has just been published by the *Engineer* and has caused a good deal of attention and interest.

The *Cardium* is one of the largest tank steamers afloat; her dimensions are 410 by 33.2 feet, and the dead weight carrying capacity nearly 9,000 tons.

The machinery is of the triple expansion type, having three cylinders, 28, 46, and 77 inches in diameter, with a stroke of 48 inches, and is placed in the after end of the vessel, as is usual in tank steamers.

Steam is supplied by three single-ended, cylindrical, multitubular boilers, working at a pressure of 180 pounds per square inch. An additional boiler is also placed on the main deck for auxiliary purposes; this boiler is also fitted to burn oil. The vessel and machinery have been designed so that either coal or liquid fuel can be used.

The oil is pumped from the oil tanks into what is called a settling tank. This tank is fitted with an overflow pipe, so that when it is full any additional oil that may be pumped in flows back into the fuel tanks. A glass gauge indicates the amount of oil in the settling tank. The oil is drawn by a small pump from the settling tank, and is forced at a pressure of about 60 pounds through a coil which is contained in the smoke-box, thus heating the oil, which then passes through a small collecting chamber into the burners, where it mixes with a jet of superheated steam and hot air while being forced into the furnaces. The steam for spraying is heated by passing it through a coil in the smoke-box and a pipe in the furnace, after which it passes through a small collecting chamber, and from there in a superheated condition to the burner to mix with the hot oil.

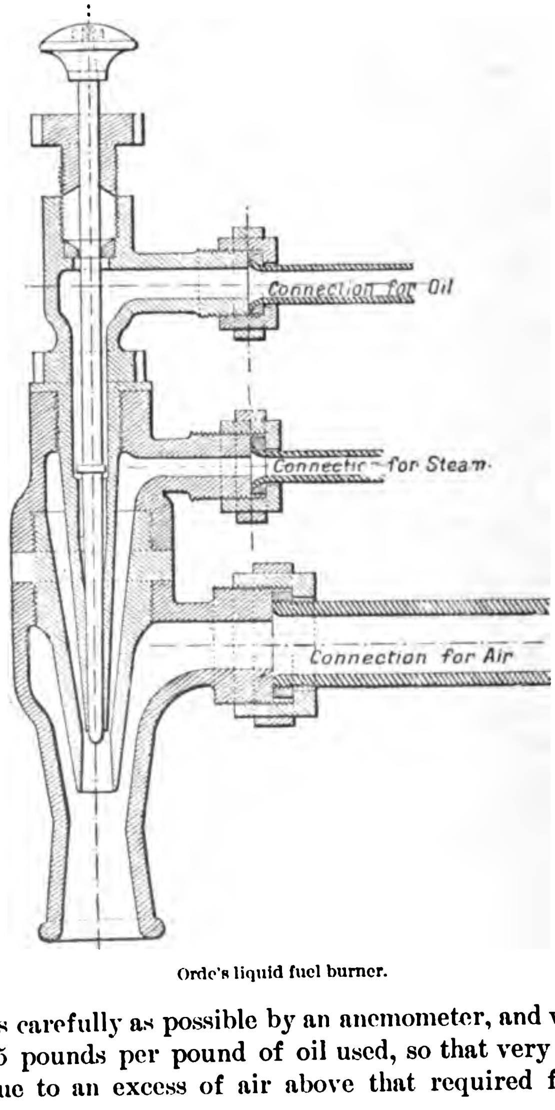
There is also a small pipe open at one end to the atmosphere, which is carried into the furnace in order to heat the air it contains, and which passes out through the other end of the pipe to the small collecting chamber, from where it is drawn into the burners. The hot oil, superheated steam, and the hot air all enter into combination in the burners prior to being injected into the furnaces.

The burner and arrangement of the furnaces are shown in the accompanying cuts.

In the trial the two after boilers were fired with coal and the forward boiler with liquid fuel. The trial lasted over three hours and the boilers were pressed to a greater extent than in an ordinary sea voyage.

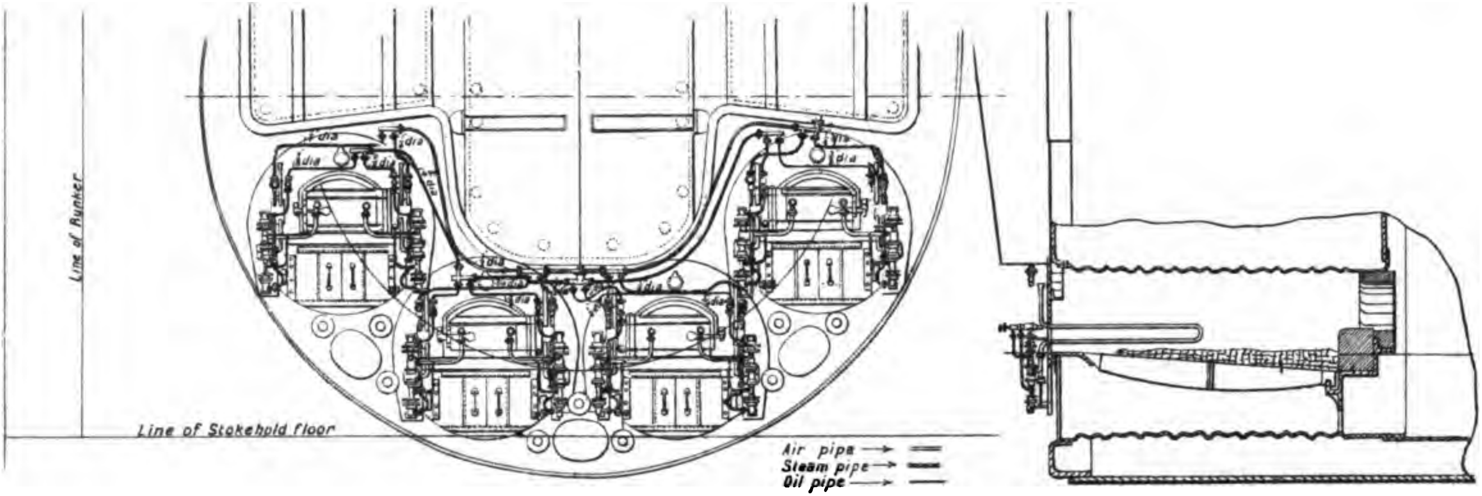
The machinery indicated about 2,700 horsepower, and on the assumption that the power was equally divided between the three main boilers, the consumption of oil per horsepower per hour was 1.1 pounds. The safety valves were blowing off more or less during the whole of the trial.

The air entering the ashpits of the boiler using liquid fuel was measured as carefully as possible by an anemometer, and was found to be about 15 pounds per pound of oil used, so that very little loss of heat was due to an excess of air above that required for complete combustion.



Orde's liquid fuel burner.

The temperature of the waste gases at the base of the funnel was



LIQUID FUEL APPARATUS OF THE S.S. CARDIUM

THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C

490 degrees, and there was very little smoke, and in order to illustrate this a wooden rod, thickly covered with chalk, was placed in the smoke-box just above one of the tube nests, so that it was within the flow of the outgoing gases. After having been exposed for a quarter of an hour it was withdrawn and found to be not discolored.

The temperature of the stokehold just in front of the ashpits was found to be 84 degrees, and this low temperature was one of the important results of the trial.

After the oil-burning trial was concluded the oil-burning apparatus was taken down, and the vessel proceeded on her voyage with all the furnaces of the forward boiler burning coal within eighty minutes from the time the dismantling of the oil apparatus was begun.

On the vessel's arrival at Suez on her eastern trips the apparatus will be again replaced and oil fuel will be used.

An examination of the furnaces after the trial showed that they had not suffered any harm.

It will be seen by the cuts that two burners are fitted to each furnace. The oil being forced under a slight pressure prevents the burners from getting clogged. A quantity of fire-brick is laid on the fire-bars, and it is only necessary in order to use coal to haul out the broken fire-bricks and remove the burners.

The following article, read before the Society of Arts by Sir Marcus Samuel, has many details of interest, showing the advancement taking place in the use of liquid fuel:

> The subject of liquid fuel, although now coming into great prominence in England, is by no means a novel one. Petroleum has been in use for this purpose, both in Russia and America, for very many years. Its advantages, compared with coal, are well known and appreciated, and the sole obstacle to its universal adoption has been that the supply has been insufficient hitherto to warrant arrangements being made, except in Russia itself, for its use. Prejudices have to be overcome, the means of using treasure has to be shown and proved, and in such an article as liquid fuel not only has transport got to be provided, but special arrangements for storage have to be made, and it was also obvious that if practical success is to be obtained liquid fuel will have to be sold at a price which will enable it to compete with coal. *Ab initio* this should be easy, when the cost of labor in mining for coal is taken into account, together with its transport from the fields where it is found to a place of shipment, and also the great cost incurred in placing it on board and discharging it, and the space occupied by it in the hold of a ship (this being about 45 feet to a ton of 20 cwt.), and, little as this is known and realized, the danger of transport arising from the highly inflammable gases contained in eastern coals renders fires in holds and bunkers far more numerous than the public are at all aware of. It is, of course, impossible to transport oil in bulk in steamers built for ordinary merchanise. Special arrangements have to be made by which the cargo is broken up into sections fixed by the regulations of the Suez Canal as not exceeding 400 tons in any one compartment. In the tank steamers cofferdams are placed fore and aft for isolating the oil against danger from the boilers or furnaces, which in these ships are placed quite in the after part of the vessel, a practice which it is a great pity is not adopted in more steamers, because the risk of accident from the breakage of the shaft is almost nonexistent in this form of structure, the lead being a small one, and the shaft being under the

constant observation of the engineers, since there is no tunnel at all. Under the regulations of the canal company pumps are provided which are capable of a minimum discharge of 500 tons of oil per hour. To show the progress of the business, I may state that the first steamer employed in the business of transporting oil in bulk through the Suez Canal was a vessel of 4,000 tons burden of oil, whilst the largest of those employed now carry 6,500 tons, and we have three steamers in course of construction to carry 9,000 tons of oil each, or 3,000,000 gallons. The facilities for landing and handling oil necessarily differ very much at various ports. At Nagasaki, Japan, the steamer lies next to the wharf, whilst at Kobe, Japan, a pier had to be constructed, it being impossible for a steamer to get alongside. At the port of Madras a breakwater of almost a mile in length had to be constructed before water sufficiently deep to allow a steamer of the size employed in this trade to get near could be found, and even then a contrivance had to be constructed to connect the discharging pipe of the steamer with the breakwater. In spite, however, of these drawbacks it is found that a steamer can easily discharge into the tanks, placed at 1 mile distant from the ships, at the rate of fully 200 tons an hour. As an example of the progress of liberal ideas, I may mention the installation at Bombay, where permission to land the oil was only given some two years ago and after experience had shown the immunity from danger attending the transport of oil in bulk. These tanks are placed almost in the middle of the shipping. Railway sidings have been taken right up to them, whence oil is pumped into the tank wagons for conveyance all over India.

An enormous future lies before this fuel, even if it only depended on its relative cost compared with coal; but when we come to the collateral advantages it enjoys, the benefits of using it, as compared with coal, are simply overwhelming. It is unfortunate that it should be so, but one can not fail to recognize the fact that the calls for purposes of war must take priority to those of peace, and the first great advantage to vessels of war, especially to torpedo boats, in using liquid fuel, as compared with even the best coal, is the entire absence of smoke arising from its employment. When combustion is complete—and this is very important, engineers having not yet found out how to handle fuel, and complete combustion does not take place and smoke is caused—not a trace of smoke issues from the funnel of a vessel using it. How important this is to torpedo boats the least initiated can understand, but it is not less so to cruisers, or even to battleships, which, when using liquid fuel, could shadow an enemy's fleet without being detected. Under the system adopted in the *Haliotis* steam is used to spray the oil, but this is certainly not the most economical method, and already a system has been found, invented by a Dutchman, called the Kloos system, which entirely dispenses with the use of steam. One main point of difference between the burning of coal and liquid fuel is that while coal remains quietly in its place until it is burnt liquid fuel would offer too small a surface to the air when lying in a tank to burn with so much heat as is required. It has, therefore, to be sprayed out in small particles to augment its surface. If, however, the oil is sprayed mechanically, the rush of cold air chills the spray and many of the small drops reach the funnel before combustion has taken place, thus producing smoke and soot. By heating the air well above the burning temperature of the oil before it reaches the spray this is remedied, and combustion takes place freely. In the heated air system the oil is forced at about 50 pounds pressure through a Körting's sprayer into the furnace. In this sprayer the current of oil has to pass a screw thread, which gives a rapid turning motion to it, so that the centrifugal force causes the liquid to fly out in dust. The air is brought by a guiding plate at the back of the furnace, returns along cast-iron ribbed plates, which are heated by the flames above it, and meets rectangularly the current of fine sprayed-out oil, the air being heated to about 500° F. As the hole in the sprayer through which the oil is injected is under a sixteenth of an inch in diameter, the liquid must be well filtered, and to assist the centrifugal force in spraying it out in fine particles the oil is heated to about 220° F.

The advantages of the use of liquid fuel in steamers are even more manifest than in its employment on land. None but those concerned in the actual management of steamers know what trouble and anxiety arises from the employment of what is known as the "black element," namely, the stokers. By the use of liquid fuel the services of these men are almost entirely dispensed with, because oil flows by gravitation from service tanks placed well above the boilers, direct to the furnaces. The expansion and contraction caused by the frequent opening of the furnace doors is entirely avoided, and the life of a boiler consequently greatly prolonged. No ashes are made, and the strain and distress to firemen of heaving these overboard before commencing their watch is entirely saved, and no grit (so deadly in its working to delicate parts of the engines) is created. I fear it is only a practical expert who will realize how much this means. To anyone who has seen the manner in which the large crew needed on a torpedo boat or destroyer are berthed, in consequence of having to stoke the enormous boilers used upon these craft, the fact that under the use of liquid fuel the crews of these vessels can be reduced to less than half of those now necessary is, in itself, an argument so overwhelming that, were this its only advantage, it would suffice to compel its introduction into this class of vessels by those in power; but when it is borne in mind that men in torpedo craft literally carry their lives in their hands, depending solely on the speed of the vessel, and not upon her armament, it is clear that a great step is attained when the crew carried upon these vessels is reduced. Oil can be carried in spaces which it is impossible to utilize in any other way, and especially in such craft as torpedo boats, where the form of the vessel under water renders the attaining of stability a difficult problem. Oil carried in the bottom of the steamer, below the water line, would be impervious to shot, and, by the system of service tanks patented by Sir Fortescue Flannery, as oil is pumped out of the ballast tanks of a steamer water can readily be taken in to replace it, because if the mixture is put into a service tank, and allowed to settle, water is quickly precipitated to the bottom, and can be drawn off, the oil remaining being pumped pure into the second service tank, whence it flows to the bunkers, and it can readily be conceived how many spaces now lost in vessels can be utilized for the storage of oil, allowing a much greater weight for armament or quantity of cargo to be carried in space now used for bunker purposes only, or lost entirely through being too small or inaccessible for the storage of coal. The importance of the new departure has been promptly recognized by Lloyd's, which, I am glad to say, has issued regulations allowing liquid fuel, having a flash point of over 200° F. to be carried in steamers' ballast tanks, and this will greatly facilitate its general use. The much longer time that a vessel equipped with liquid fuel can keep at sea is also a factor which must not be overlooked, and, provided relays of supplies are furnished at ports not too far apart, the carrying capacity of an ordinary merchantman is increased by some hundreds of tons, dependent necessarily on the size of the vessel, whilst the saving in time in taking in oil instead of coal as bunkers can be best estimated when I state that oil can easily be put on board at the rate of 300 tons per hour, and this without the slightest dirt—a great characteristic of the Borneo oil being, too, that it is almost odorless.

The experimental stage in the burning of liquid fuel, as stated at the commencement of this paper, has long since been passed. The uses for it in Russia itself are innumerable, and the latest statistics show that no less than 7,000,000 tons per annum are consumed in Russia for liquid fuel alone. Lately it has been largely adapted for naval purposes as well, whilst for many years the steamers navigating the Caspian Sea have used it exclusively. There are no less than eight steamers at present engaged in the Eastern trade which are fitted for it, and where the results attained have answered the expectations of their owners beyond their most sanguine anticipations, whilst large numbers of vessels are under construction expressly for the use of liquid fuel, and a great number of steamers hitherto burning coal are also being altered. In the far East tanks have been erected at ports ranging from Yokohama to Suez, including all the Indian ports, whilst cargoes of the Borneo oil have also been landed at the principal ports, and 4,000 tons is at the present time on passage to London. Under the advantages which I have enumerated it will be understood that it is rapidly going into general consumption. In Europe the Russian, the Italian, and the German navies have partially adopted it.

In the earlier experiments with liquid fuel the oil has generally been pulverized by steam. By this system the oil coming from the burner is pulverized by a jet of steam and projected into the furnace in a finely divided state, drawing in a current of air for the combustion. Some of the burners that have been used in the navies of Italy, Russia, Germany, and France are shown in Figs. II, III, and IV. These pulverizers or burners are continually being improved and changed, but the different systems of mixing the air, oil, and steam and of pulverizing the oil are shown by these cuts.

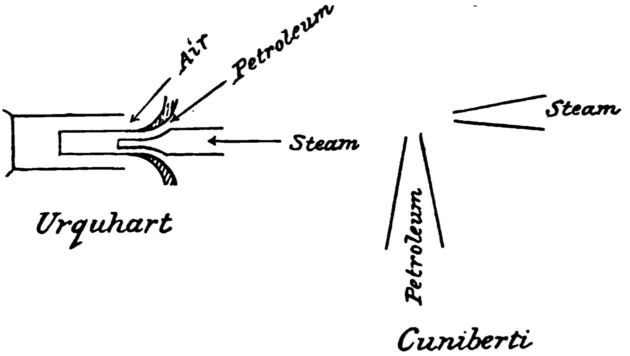


FIG. 2.

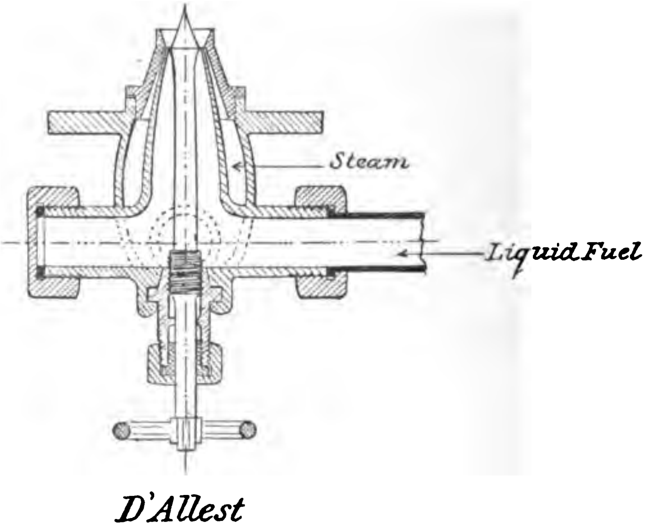
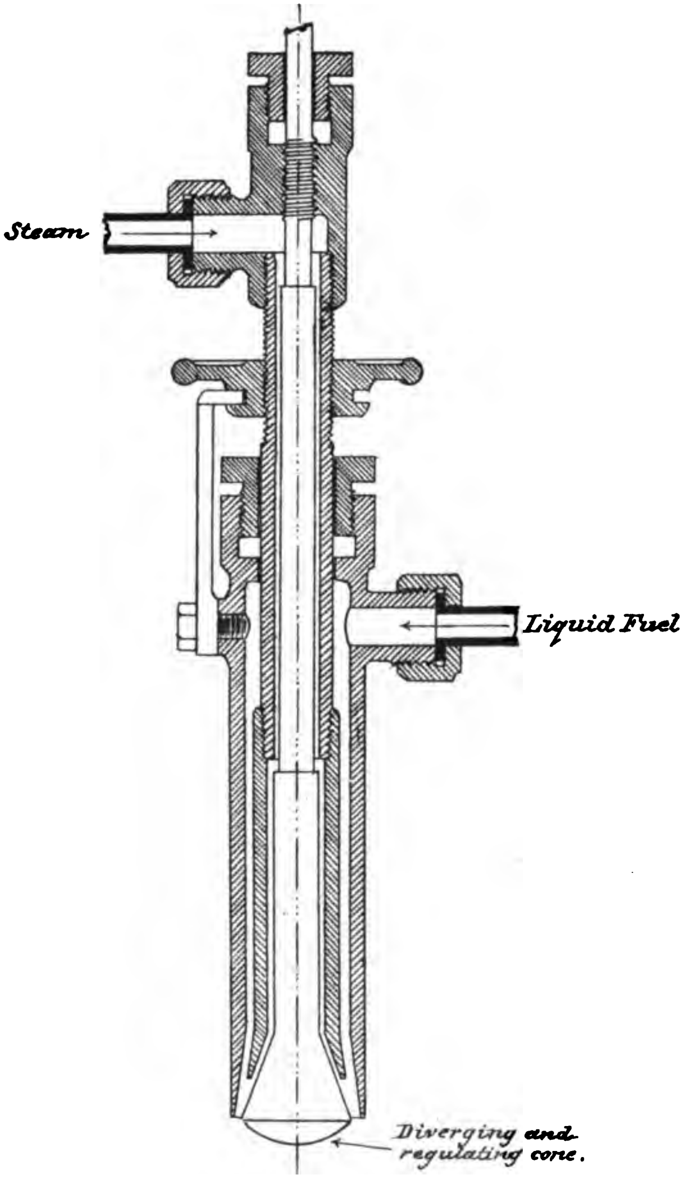


FIG. 4.

Fig. III.



Kauffmann.

THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

The burners are fitted to the front of the boilers, often to the furnace doors and so arranged that the doors can be opened without removing them. The system for burning the oil consists of—

1. Tanks for the storage of the petroleum. When the coal bunkers are used for this purpose they are divided into compartments. This prevents the loss of the whole compartment of oil in case of penetration by shot.
2. Feeding reservoir high above the boiler floor from where the oil flows by gravity and where, in some cases, it is kept under slight pressure.
3. Pumps for forcing the petroleum from the tanks to reservoir.
4. Burners.
5. Piping to carry oil to burners.
6. Piping to carry steam to burners for pulverizing the oil.

The petroleum is found very liable to leak, more so than water, and precautions must be taken to prevent this in the tanks. The petroleum is generally warmed to cause it to flow more readily.

The chief disadvantage against the pulverization of the oil by steam is the great amount of fresh water used, often amounting to 6 per cent. It has been necessary, in some cases, to provide special evaporators to generate the steam to pulverize the oil. This great amount of fresh water required, in addition to the amount required for the boilers, is a serious drawback on board ship, and some torpedo boats so fitted have been unable to go to sea.

The furnaces have to be especially arranged for burning liquid fuel, the bridge being generally removed and brick linings fitted to prevent the flames impinging directly upon the plates. These internal arrangements of the furnaces have a great influence upon the results. Some experiments have given excellent results in cylindrical boilers with certain burners and internal arrangements, but when these fittings were applied to water-tube boilers the results have not been satisfactory, the experiments showing that each type of boiler must have its own kind of burner and internal arrangements for satisfactory results. In some cases the experiments on torpedo boats have been unsatisfactory owing to the unconsumed gases escaping in flames from the funnels when the boats have been forced to high speeds.

One great drawback to the system is the difficulty of starting fires. Steam is required for the action of the burners, or pulverizers; and as the steam can not be furnished by the boiler when getting up steam, other means must be resorted to. On men-of-war, where steam is kept up in auxiliary boilers, steam can be furnished for this purpose.

The regulation of the fires is very simple, and the fire-room force can be greatly reduced, one man being able to care for many boilers. It also allows the fire room being kept very clean.

The great disadvantage of the use of steam in the pulverization of the oil has led to many experiments in the use of air for pulverization. The Russians have taken the lead in these experiments on board their men-of-war and, according to their own accounts, have solved the problem. Exhaustive experiments were carried out with great success on board the *Rostislav*, where the oil was pulverized by mechanical burners (pneumatic) instead of by steam. In fitting the *Rostislav* for oil, a great saving of space was made. These experiments have been so successful as to cause the Russians to apply this system of burning petroleum to some of their most recent battleships and cruisers, some of the boilers being fitted to burn oil and some retained for use of coal. Plans are being prepared for the construction of depots for the storage of oil. The tanks are to have a capacity of 17,000 tons, and old marine boilers will be used in their construction. A special iron steamer is also contemplated, of 1,000 tons capacity, fitted with the necessary apparatus for the transportation of petroleum from the depots to ships.

Owing to the great success claimed by the Russians in their navy in the burning of petroleum without the use of steam as a pulverizing agent, and to the great disadvantages of steam for this purpose, attention is called to the cuts and description of the Kermode system, shown below, as applied to a marine boiler. Experiments were carried out by the Wallsend Slipway and Engineering Company, and the results are given in the accompanying description.

The advantages claimed for this system are: All the oil is consumed and perfect combustion obtained. Smoke is dispensed with and coal or other assisting fuel is not required. The apparatus does not interfere with the ordinary arrangements of a steam boiler, and the necessary change for the use of coal can be quickly effected.

KERMODE'S APPARATUS FOR BURNING LIQUID FUEL.

The systems of burning liquid fuel mostly in vogue spray or "atomize" the oil by a jet of steam, and in this condition deliver it to the furnace. Kermode's system differs from these in that the oil is first vaporized by being mixed with hot air, which is supplied under pressure for the purpose. The amount of air supplied this way need not necessarily be the full amount required for the perfect evaporation of the oil, as the burning vapor induces a current of air sufficient to meet all further requirements. The advantages of this arrangement for steamships will be evident to all. As the introduction of salt water into marine boilers is incompatible with good working, the use of a steam jet whose consumption may be estimated at 3 per cent of the steam raised would require an immense battery of evaporators to provide make-up feed. In any case the steam jet is an uneconomical device, and an equivalent spraying power can be obtained by air pumps for one-half the expenditure of fuel.

The illustrations show the apparatus employed by "Kermode's liquid-fuel system" as applied to a marine boiler. The blowing engine (fig. 3) delivers air into a 4-inch main, from which a 2½-inch pipe branches to each furnace. This pipe goes through the furnace front (fig. 4), along one side of the furnace (fig. 3), across the front of the bridge, and back along the other side of the furnace. Its extremity is made in

KERMODE'S APPARATUS FOR BURNING LIQUID FUEL.

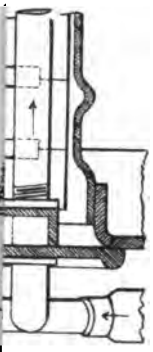


Fig. 9.

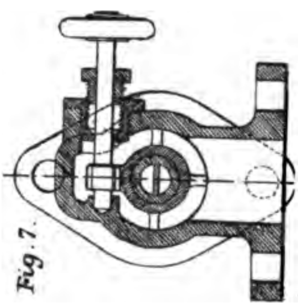


Fig. 7.

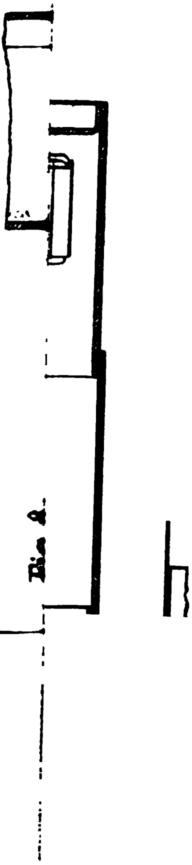


Fig. 8.

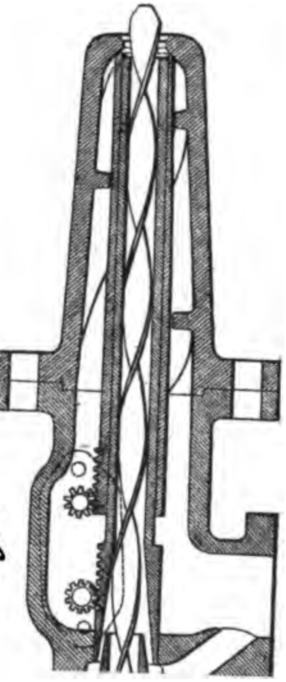


Fig. 6.

the [illegible] is swept forward by a sharp current of hot air, which envelops the nozzle. This current can be regulated with great exactitude. A further compressed-air supply is given when combustion is about to commence, while a third supply is caused by the induction of the flame or by the draft. This latter supply comes through the hollow furnace front, passing between the inner and outer plate and escaping through the coned opening around the burner. The "grate" is made of special fire-clay blocks, which were constructed for use in a series of trials of the apparatus by the Wallsend Slipway and Engineering Company, of Newcastle-on-Tyne. Figs. 8 to 11 show the arrangements adopted in a second set of experiments with cast-iron fire bars in place of fire bricks, these bars being covered with asbestos lumps. The fire-clay blocks were also covered with asbestos, although this is not shown in the engravings. The arrangement of the burner is similar in principle to that described in reference to the previous figures, except that the oil passes first through a vaporizer tube inside the furnace. This device, however, is not found to be essential. In any case the burners hinge upon the air and oil cocks, which are attached to the boiler, and therefore if it is necessary to examine the front of the burners they may be withdrawn from the furnace, the act of withdrawal shutting off the supply of air and oil, and thus preventing accident to a careless attendant.

Kermode's liquid-fuel system.

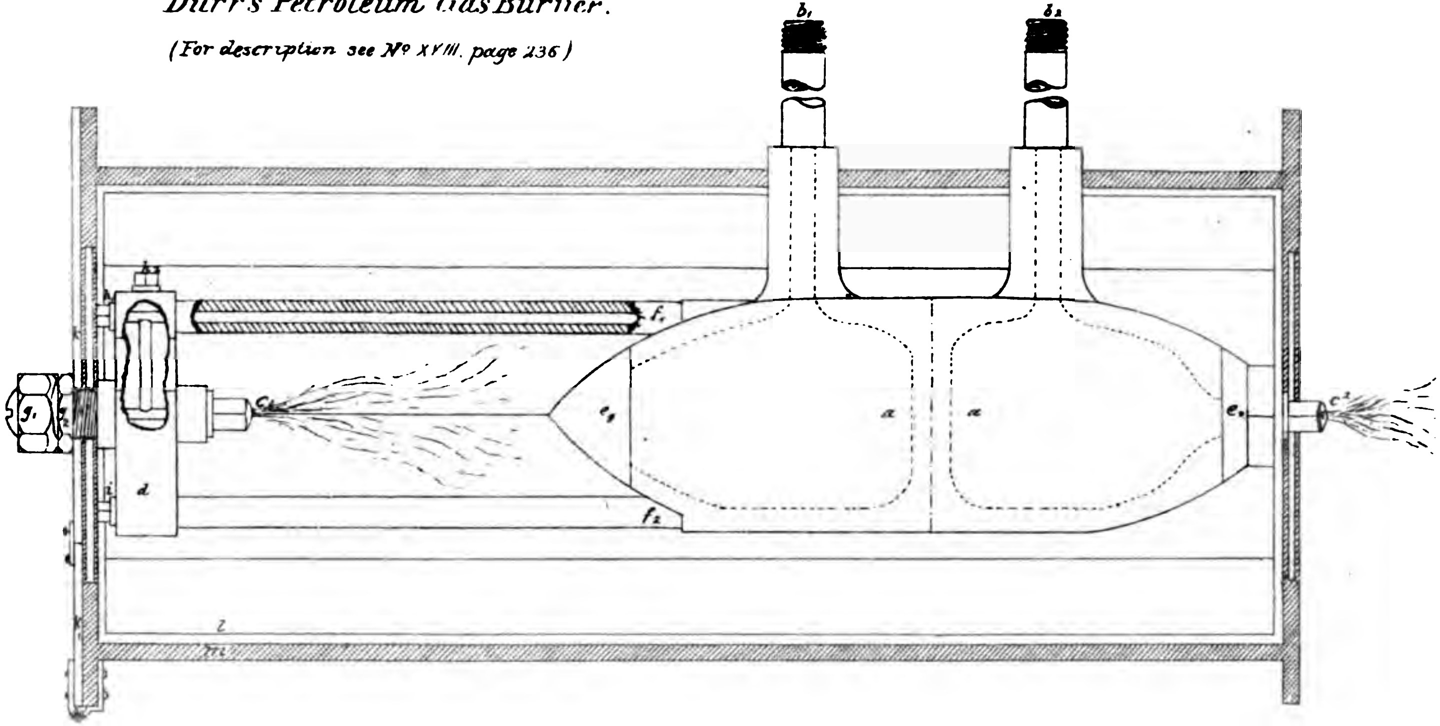
Date of trial	Sept. 6, 1899.	Sept. 14, 1899.	Sept. 19, 1899.	
Duration of trial	3 hours.	4 hours.	2 hours.	
Class of oil used	Borneo crude.	Borneo crude.	Borneo crude.	
			First hour.	Second hour.
Mean pressure on boiler ... pounds	111	110.5	109.8	110.4
Total gallons of water evaporated	2,427	3,550	940	955
Total pounds of water evaporated	24,161	35,323	9,362.5	9,511
Gallons evaporated per hour	809	887.5	940	955
Pounds evaporated per hour	8,053.7	8,830.75	9,362.5	9,511
Pounds of water per pound of oil	11.1	10.9	10.93	10.92
Pounds of water per pound of oil from and at 212 degrees F.	12.9	12.75	12.85	12.84
Mean temperature of feed water ... degrees F.	89	89	83	83
Temperature of oil in measuring tank ... degrees F.	68	68	67	67
Total gallons of oil consumed	225.3	337	88.8	90.2
Total pounds of oil consumed	2,174	3,244	856.5	870.3
Gallons consumed in one hour	75.1	84.2	88.8	90.2
Pounds consumed in one hour	724.7	811	856.5	870.3
Pressure on oil at burner ... pounds	4.3	4.3	4.3	4.3
Specific gravity of oil	.965	.965	.965	.965
Temperature of uptake ... degrees F.	650	665	720	720
Smoke at funnel top	Light brown.			
Air pressure in burner ... pounds	3	3.2	3	
Revolutions of blowing engine	310	350	820	
Pounds of oil per hour per square foot of grate	18.1	20.3	21.5	
Pounds of water per square foot of heating surface	4.75	5.5	5.5	

7.5 per cent of water in the oil is allowed for in the above results.

At the conclusion of a trial it was found that the effect of closing the air valves was to maintain the heat of the boiler very effectually. If the trial ended with 110 pounds, then, after twenty-four hours, there would be a pressure of over 20 pounds per square inch still remaining—enough to drive the pumps to restart operations. If the pressure is entirely lost, then steam is got up at first with what Mr. Kermode calls a "starter." It is claimed that no dangerous leaping out of flame is experienced at lighting up, as it is only necessary to put a small torch through the sight-holes in the furnace front, and the oil catches fire as if it were gas. If it be desired to change to coal, all that is necessary when cast-iron bars are used is to swing back the burners, remove the asbestos, and fire up in the usual way.

Dürr's Petroleum Gas Burner.

(For description see Nº XVIII. page 236)



a Gasifier, divided in two compartments.
$b_1 b_2$ Pipes for petroleum.
c_1 Rear burner; c_2 Front burner.
$e_1 e_2$ Screw caps for closing rear and front chamber.

f Tube for conducting petroleum gas to rear burner.
$g_1 g_2$ Nuts for closing rear burner.
$h_1 h_2$ Screw caps for cleaning holes.
m Exterior casing.

i Assembling screw.
k Door for closing burner.
k_1 Small door for seeing.
l Lining or casing of fire clay.

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V.

ELECTRICAL NOTES.

By Lieutenant LOUIS R. DE STEIGUER, United States Navy,
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GENERAL NOTES.

The principal advance in the use of electricity on board men-of-war of the different powers has been in the application of motors to drive the auxiliaries. In some cases this increased use of motors has taken place slowly, and for such auxiliaries as were favorably situated. In other cases, the use has increased to such an extent as to be applied to most of the auxiliaries on board ship, even to the blowers in the fire rooms. In the most advanced cases are included the following auxiliaries: Capstans, windlasses, ammunition hoists, blowers for ventilating the hull engine room and fire room, winches, machine shops, ash hoists, turret rammers, turret training gear, draining turbines, elevating gear for guns, boat cranes, pumps, and steering gear. Development has necessitated the installation of more generating sets in the new ships, for which purpose greater space is being allowed, and in some cases, a higher voltage adopted.

The reports of experiments and tests of electrically-run auxiliaries have generally been favorable to their use; but there is a hesitancy among naval officers abroad and at home to use electrical auxiliaries in exposed positions until some have been tried for a period of years and have proved their lasting efficiency.

The different conditions under which motors work on board ship have made their application to the scattered auxiliaries a difficult problem to solve. They have been applied to fans for a much longer time than to other auxiliaries. The fans being in protected positions and the load being practically constant, their use for this purpose has been very satisfactory. The greatest difficulty has been in their application to capstans, cranes, winches, and turrets, where the loads are variable and suddenly applied, and where, in many cases, they are exposed to the seas and dust in coaling. Upon this subject Mr. A.

Siemens, in his paper before the British Association, has written as follows:

> Driving auxiliary machinery by small steam engines or by hydraulic power necessitates a network of piping all over the ship. This is difficult to arrange neatly, gives endless trouble through leakage, and, in addition, there are waste products from all the auxiliary steam engines, and their disposal requires additional pipes and complications. All this inconvenience is avoided by employing electric motors, and for certain purposes where the load on the motor does not vary much, they have generally been introduced.
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> That their use has not been extended is due to the difficulties which arise from variations in the load on the auxiliary machinery. Taking the case of a winch, it frequently happens that the strain on the cable increases sufficiently to stop the movement of the winch altogether, and this would cause the current through the electric motor to rise to a dangerous extent. It is impracticable to protect the motor by a fuse, as the interruption of the circuit through the blowing of the fuse would allow the strain being taken off the winch, and in most nautical operations it is necessary to keep the strain on. There are two methods in use to overcome this difficulty. One is to employ shunt-wound motors running continuously and operating the winches through friction clutches. The second is to employ special cut-outs in connection with series-wound motors. By these cut-outs the current through the motor is not interrupted altogether, but if the winch or other machinery is stopped so that the current becomes excessive, the main current is interrupted and a by-pass only left, in which sufficient resistance is inserted to allow only the maximum safe current to pass.

Motors for auxiliaries on board ship are required to be of the inclosed type, hermetically sealed, to protect them from the seas and dust in coaling; to be capable of standing a great load being suddenly thrown upon them without burning out; to be simple in arrangement, so that the enlisted man can readily learn to run them, and to be accessible, so that they can be easily cleaned and inspected.

Electrical experts have written a great deal tending to show the economy and efficiency of this method of distribution of power, and the following advantages are claimed for its use:

1. The great facility with which the distribution can be carried out; it being much easier to run wiring to a distant auxiliary than the piping of steam, hydraulic, or pneumatic auxiliary.

2. Heating of the living spaces. The piping for steam, running to the different auxiliaries, must pass through living spaces, frequently rendering them unfit for life in the Tropics.

3. Danger to life. The bursting of a steam pipe in time of action might cause loss of life and great suffering. The wiring makes a much smaller target than steam piping, and would, therefore, be less liable to damage by shell.

4. Efficiency and reliability. It is claimed that motors have been improved to such an extent as to be applied in the commercial world to almost all kinds of motive power, and that the navies have not kept pace in their use; that they can be installed to perform their functions under the most trying circumstances and in very exposed positions;

that the motor is simpler than a steam or hydraulic engine, and that the men around the deck can readily learn to use them intelligently, extreme cleanliness in their care being the chief requisite.

The late Mr. S. Dana Green, in his paper read before the American Institute of Electrical Engineers, has brought forward the following data upon the efficiency and reliability of motors on board ship:

> The modern first-class battleship requires about 2,000 I. H. P. to drive all the auxiliaries at full load, and the first-class cruiser about 1,200 I. H. P. These auxiliaries, however, are never all in use at the same time, using maximum power, and it can be assumed that about one-half these amounts (i. e., 1,000 I. H. P. and 600 I. H. P.) will be required at one time.
>
> Efficiency: Here the contrast is very striking in favor of electricity, surprisingly so to one who has not seen the actual economy figures of steam auxiliaries.
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> There remain the two important factors of simplicity and reliability to be considered. No one who has had experience with the modern well-designed and well-insulated carbon-brush generator or motor can have any doubt as to its greater simplicity as compared with steam engines. There are no joints to keep tight, no nuts or bolts to set up, no packing to renew, no cylinders to cut, and only two self-oiling bearings, as compared with a dozen or more oil cups on an engine. In fact, it is difficult to imagine a simpler piece of machinery than the modern dynamo. It seems like a return to elementary principles to discuss such a point; and yet many men aboard ship imagine the dynamo a most complicated affair, simply because they know nothing about electricity, and think everything connected with it mysterious and complex. This feeling is not confined to seafaring men, as we all know.
>
> The question of reliability is a vital one, for no matter what the advantages with respect to safety, economy, and simplicity may be, if the electric auxiliary can not be relied upon at any and all times to do its work it is a failure and must be discarded. It must not only be able to work well under normal and favorable conditions, but it must be able to stand a certain amount of abuse and neglect. Stress of weather and other conditions, particularly during a war, sometimes play havoc with the established routine of a ship, and the sailor's tools must not only be sound; they must be hardy. The normal conditions aboard ship are not favorable to ordinary electric apparatus, but this simply means that apparatus for such work must be specially designed and built to meet the conditions. The ordinary motor would not last long under a street car; nevertheless thousands of car motors are built and sold every year which run day in and day out with a remarkably low maintenance account. Similarly, apparatus for ship work must be specially insulated, a larger margin of capacity must be allowed, and in exposed places it must be thoroughly inclosed. Several years ago an English manufacturer asked permission to install an electric deck winch on the spar deck of a new cruiser fitting out at Portsmouth. When the captain who was superintending the fitting out of the ship saw it, he gave orders to have the deck hose turned on the motor for ten minutes, and then to operate the winch. The manufacturer protested and said the motor was not intended to be abused in that way. "Then take it off the ship," said the captain, "for I can not guarantee that we will ship no seas during our cruise, and I want that winch ready for service whether we ship seas or not." The captain was quite right; the motor was taken off, and a "rough-and-ready" steam motor substituted.

The writer then compares the driving of auxiliaries by steam and electricity, giving the steam consumption of the *Minneapolis*, obtained from observations made during a run of this ship from Gibraltar to League Island, Philadelphia. Indicator cards were taken on all the

auxiliaries fitted for the purpose (31), and the losses from leakage, condensation, and radiation were carefully estimated, and the water evaporated carefully measured.

The average weight of steam used by the main engines per hour was 33,620 pounds, and by the auxiliaries 10,146 pounds. That is, the auxiliaries consumed nearly 25 per cent of the total coal used. The main engines consumed an average of 20.83 pounds of steam per I. H. P. per hour, and the auxiliaries an average of 119 pounds per I. H. P. per hour (the lowest being 55.06 pounds and the highest 318.68 pounds per I. H. P. per hour). These results are not exceptional; in fact, they are probably better than the average obtained on most war ships or merchant vessels. The new British cruiser *Powerful* (14,000 tons displacement) is reported to have used 8,300 tons of coal from England to Hongkong, of which 3,400 tons (or over 40 per cent) were required for the auxiliaries.

Under the most favorable conditions the auxiliaries of a large ship probably consume at least 20 per cent of the total coal and water used. This is more than twice as great as the consumption in a modern central station, and there is no good reason why as good results should not be obtained afloat as ashore.

Let us assume a required central-station capacity for a first-class battleship of 1,000 horsepower effective at the motors. The present standard E. M. F. for naval installations is 80 volts, and for the merchant marine about 100 volts. This low voltage was originally adopted on war ships on account of the search lights, which required 50 volts only, and it was desired to introduce as little dead resistance as possible. At this time no motors were, of course, in use, and the electric plant was used for lighting exclusively. Such a voltage is, however, entirely unsuited for a 1,000-horsepower plant. The weight of the distribution system would not only be excessive, but the size and weight of the generators would be prohibitive. The three-wire system, or a standard of 220 to 2,250 volt two-wire system, should be adopted, using the necessary resistance in the search-light circuits when they are in service; since they require a relatively small percentage of the total plant capacity, and are not regularly in use, this can be done without undue sacrifice.

The generating plant should consist of several units of the same size, so that parts are interchangeable, each unit consisting of a compound vertical engine, driving a pair of generators or a single generator, depending upon whether a three-wire or a two-wire system is used. Assuming an efficiency of 82 per cent for engines and generator, and an average line and motor efficiency of 80 per cent, the total efficiency of the system (between the indicated horsepower of the generating engines and the effective horsepower of the motors) is 65.6 per cent. In other words, to develop 1,000 horsepower at the motors will require 1,500 I. H. P. at the engines, or about 900 kilowatts generator capacity. Six sets of 150 kilowatts each, with one reserve, would be required. A good compound engine, working at approximately full load (and with six units those in actual service can always be operated at or nearly full load), will require 20 pounds of steam per I. H. P. per hour. Assuming a total efficiency of the system of 65.6 per cent, as above, it will require about 30 pounds of steam per effective horsepower per hour at the motors. If we allow 25 per cent margin for losses due to steam leakage, condensation, mechanical friction of gears, etc., we still have an economy of 37.5 pounds per horsepower per hour, as against 119 pounds, as shown by the *Minneapolis* test. In this case the auxiliaries tested aggregated 471 horsepower developed, using 56,049 pounds of water per hour. At 8 pounds of water evaporated per pound of coal, the coal consumption was 7,000 pounds per hour, or 84 tons per day, assuming that this power was required for twenty-four hours. If the water consumption had been at the rate of 37.5 pounds per I. H. P. per hour, instead of 119 pounds, the coal used per day for these auxiliaries would have been 26.5 tons, a saving of 57.5 tons, or nearly 70 per cent.

It is fair to assume that by the introduction of compound engines and improved mechanical appliances on some of the auxiliaries the average steam consumption can, perhaps, be reduced to 75 pounds per horsepower per hour, but this is still 100 per cent in excess of that required for electric drive. Assuming an average daily use of 800 horsepower, effective at the auxiliaries on a first-class battleship at sea, this difference in efficiency means a saving in water used of 360 tons per day, and in coal a saving of 45 tons a day. All steam cylinders connect with the condensers so that the water used by the auxiliaries is not lost, but is used over and over again, it being necessary to supply only that lost by leakage in the pipes and condensers. The extra pumping duty is large, however. The coal saved, on the other hand, means that with a given coal endurance (or "steaming radius") a vessel can carry from 10 to 20 per cent less coal, or, expressed in another way, with the same coal capacity she will have from 10 to 20 per cent greater steaming radius. The average price paid in the Navy for coal (including stations in all parts of the world) is probably at least $7 per ton. There is, therefore, in the case assumed, a direct saving in running expense of $315 per day for coal alone. It may be argued that a vessel in a port does not use her auxiliaries to the same extent that she does at sea, and that, therefore, the comparisons made are misleading. This may be true as to actual saving in pounds of coal and water or in dollars and cents, but the percentage differences hold true in any case. Furthermore, a ship is built to keep the sea, and her efficiency and usefulness are measured by her performance at sea, and not when incidentally or accidentally in port. Her weights are distributed and apportioned, and her power, speed, and "steaming radius" are designed for sea conditions, and it is these conditions alone which should be considered.

The following is the practice followed by the principal maritime powers in the installation of the electric plant on board ships of war:

It is the custom in the British navy to place three or four dynamos of 600 amperes and of 80 volts in their large battleships and cruisers and three dynamos of 400 amperes in their smaller cruisers. One generating set can generally supply all the lights for the usual work of the ship. Some of the large cruisers and battleships are supplied with 1,000 to 1,500 lights.

The Admiralty has recently used motors for the after capstans, for boat hoisting engines, for coal and ash hoists, and, in the *Terrible*, for training the 9.2-inch guns. The *Powerful* and *Diadem* classes were supplied with electric ammunition hoists, but it has not been the practice in the British navy.

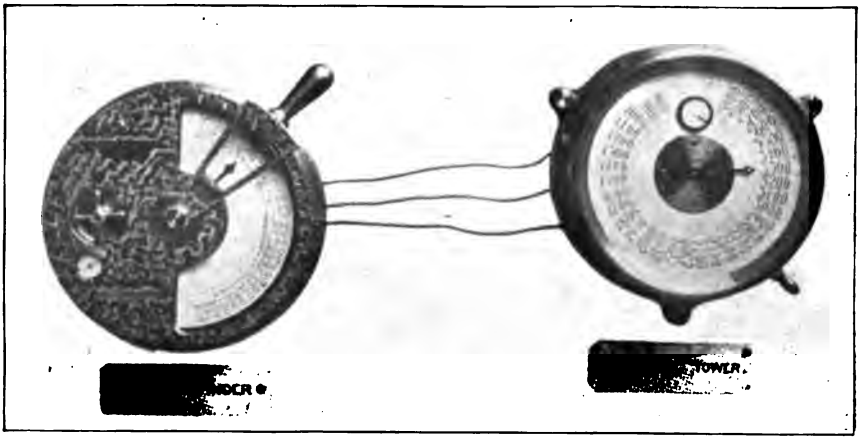
The switch boards are not arranged for parallel working, so that the different circuits have to be thrown on one or the other of the dynamos. The bars are arranged in a horizontal position. Double wire circuits, lead covered, with vulcanized india-rubber insulation, have been used. The wires and cables are run along uncovered battens, fastened to the bulkheads, so that they are visible for inspection and repairs.

The Barr and Stroud transmitting and receiving instruments have been experimented with by the British navy, and have been placed in the *Canopus*. Some of the Japanese ships have been fitted with these instruments, and several governments are experimenting with them.

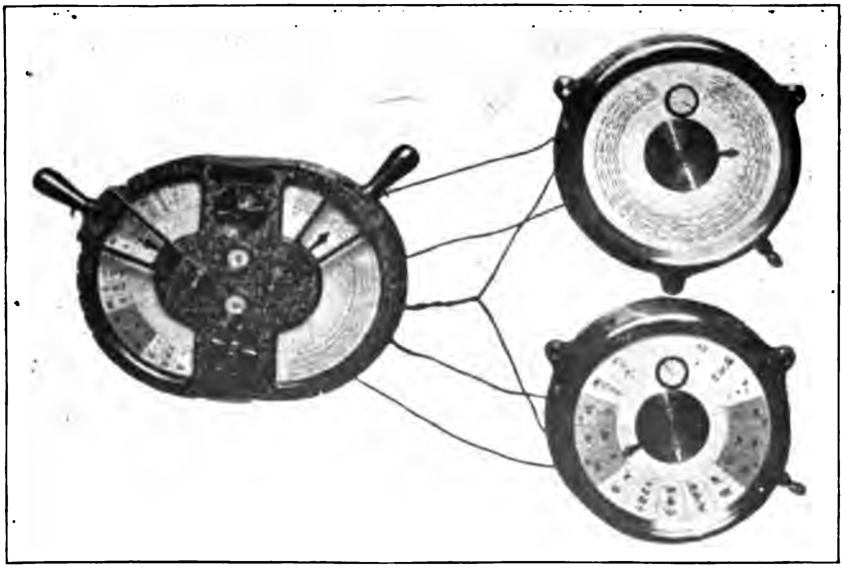
In the Japanese ships the orders have been placed upon the dials in both English and Japanese. Those for the British navy carry, on one half of the face, ranges from 800 to 4,500 yards, and on the other half of the face various orders, such as "commence firing," "cease firing," "torpedo boats," "forward of beam," etc. One transmitter, situated on the bridge or in the conning tower, can be connected with any number of receivers situated in different batteries.

The following is a description of these instruments, issued by the makers:

> The transmitters and receivers consist of clockwork mechanisms contained in brass cases having dials affixed in front. The orders or symbols to be transmitted are disposed in a circle like the figures on a clock face, and pointers actuated by the clockwork mechanism indicate the particular order or symbol transmitted or received. These pointers and the dials are protected by plate-glass coverings.
>
> The number of separate orders or other indications that can be transmitted, depends only on the number that can be sufficiently easily read from the dials, and the dials can be made of any required size.
>
> A large number of receivers can be operated simultaneously from one transmitter.
>
> The transmitter is fitted with an outside handle carrying a small index pointer. This handle moves about the center of the dial. To transmit an order, the handle is moved until the index pointer is over the required symbol. As soon as the handle is moved, the inside pointer starts to follow it, and continues following until it comes under the index pointer, where it stops. All the pointers on the receivers move synchronously with the inside pointer on the transmitter, but not with the handle. The rate of motion of the inside pointer is constant, being controlled by the clockwork; it is, therefore, quite independent of the rate of motion of the handle, and no amount of jerking of the handle can cause the transmitter to transmit a wrong order.
>
> The energy required to actuate the clockwork in the transmitters and receivers is supplied by coiled springs in each instrument, and these have to be wound periodically. An indicator on each dial plate shows the state of winding of the springs at any time. One winding serves for the transmission of a very large number of orders, and will, no doubt, prove sufficient for many weeks of ordinary working of the instruments, but, nevertheless, the receiving instruments have been so designed that they may be wound up even while indications are being received.
>
> The connection between the transmitter and receivers is electrical; but as the current is only used to control the action of the clockwork, and not to drive the mechanisms, a very small amount of energy has to be transmitted through the wires—a maximum of one watt per instrument being all that is required. Moreover, variations in the E. M. F. do not affect the working of the instruments so long as it does not fall too low to start the transmitter.
>
> The handle of the transmitter has no mechanical connection with the inside mechanism, but actuates only electrical contacts necessary to start the pointer to follow the handle. The commutators, which make and break the currents sent to the receivers, are part of the clockwork mechanism and independent of the handle. Should the e. m. f. from any cause become too low, the transmitter will fail to act, and this is at once evident to the officer operating the transmitter by the inside pointer failing to move when the handle is moved. It must be remembered that the inside pointer of the transmitter and the pointers on the receivers move together, so that if the transmitter pointer fails to move the receiver pointers also remain at rest, and the officer at the transmitter sees at once that his order has not been transmitted. If the inside pointer of the transmitter moves at all, the receiver pointers must all move in unison with it.
>
> It will be evident from what has been above described that, as already stated, no amount of jerking of the handle can influence the transmission of the orders.



Single transmitter and receiver.



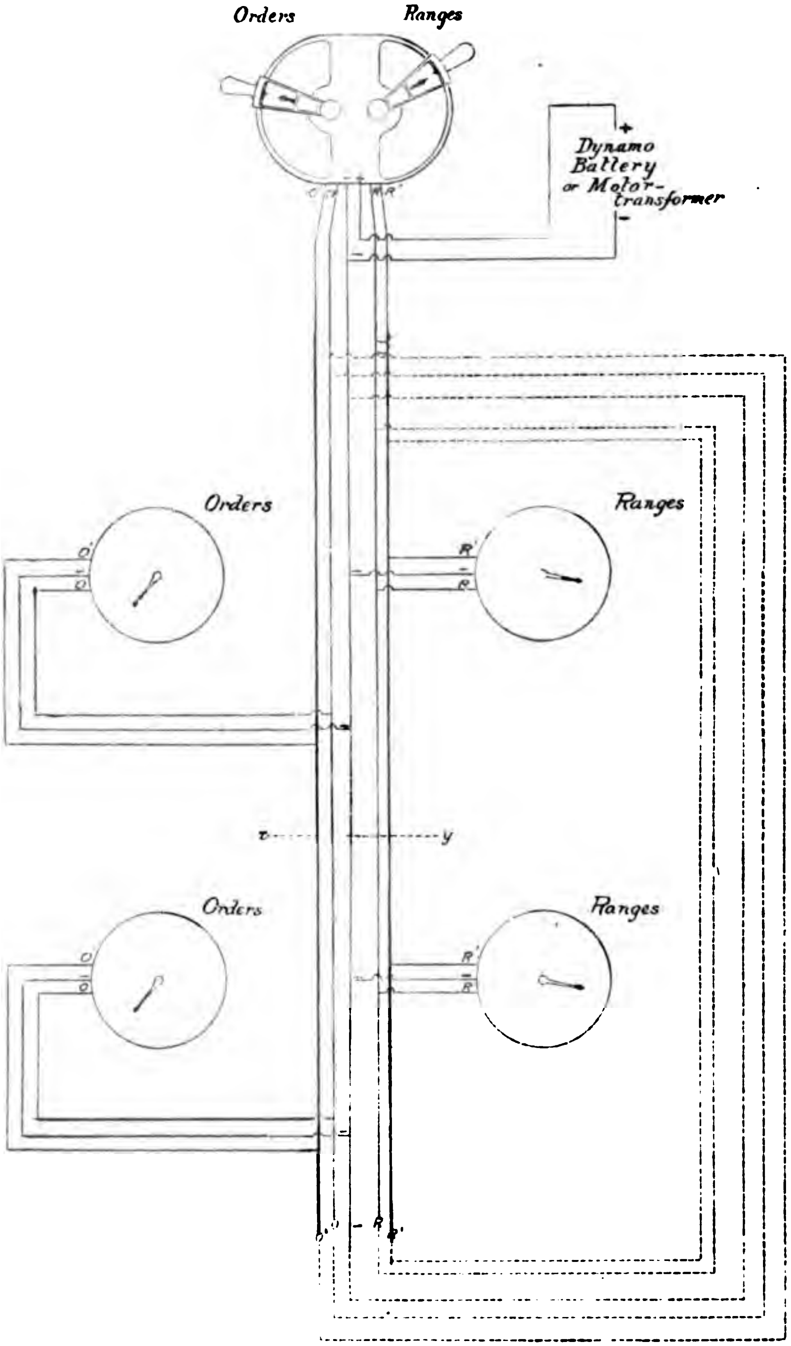
Double transmitter, range, and order receivers.

THE BARR AND STROUD TRANSMITTING AND RECEIVING INSTRUMENTS.

(These are part of an installation of 17 instruments on board H. I. J. M. S. Asama.)

The Barr and Stroud Transmitting and Receiving Instruments.

DIAGRAM OF A SYSTEM OF WIRING.



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Should a receiver be disconnected temporarily from the circuit while indications are being transmitted, it will be put out of agreement with the others, and may therefore give false orders when reconnected. To effect the adjustment of any or all of the receivers, it is only necessary to turn the transmitter handle to the stop at one end of the scale, wait until the inside pointer is under the index pointer, then turn the handle to the stop at the other end of the scale and wait as before. All the instruments will then be in agreement. It will be evident that the officer need not know what any of the receivers may be reading in order to effect the adjustment, and, as the adjustment only takes some twenty seconds to make, the officer may make the movements above indicated on each occasion on which he proceeds to operate the apparatus, if it has been for some time out of use.

Transmitters are made of two kinds, single and double. The double transmitters are equivalent to two single transmitters put into one case for convenience and compactness, and arranged the one to transmit orders and the other ranges. Such transmitters, when used for signaling to guns, are mounted in the conning tower or other commanding position, while the receivers are placed at the various gun stations.

The current for an installation may be obtained from a battery, dynamo, or motor transformer. If batteries are used, it is necessary that they should have a low internal resistance. For the instruments at present designed, 8 to 12 volts are required on the circuit.

The instruments can stand great shocks without derangement. Their working will not be in the least affected by gun fire in their immediate neighborhood.

The outer cases are made so as to be watertight.

The accompanying photographs will show the external appearance of the instruments, and the diagram shows the system of wiring for an installation.

In the case of a warship it is advisable to carry out the endless system of wiring as shown by the dotted lines on the diagram, so that if the circuit or any section of it is shot away at any place, such as *xy*, the instruments will still continue to work.

If desired, electric bells can be provided at any or all of the receivers to ring every time an indication is transmitted—that is, every time the transmitter pointer moves from one symbol on the dial to another. It is advisable in every case to have bells in connection with the order receivers so as to call attention to the change of order.

Special arrangements of transmitters and receivers can be supplied for transmitting single messages to single stations in addition to signaling the same messages to all stations. Reply instruments can also be supplied; indeed, these instruments are suited for any of the various conditions under which it is required to transmit messages from one station to another.

Electricity has been used extensively in the French navy for driving auxiliaries. France was one of the first nations to use motors for training turrets and guns.

The electrical installation in large vessels, such as the armored cruiser *Montcalm*, consists of four dynamos of 400 ampères and 82 volts, with ability to run for an hour at 500 ampères. About 500 lights are used for interior lighting.

The *Montcalm* is provided with six search-lights—one on military mast, one low on mizzenmast, and four in the battery, two forward and two aft on railways, fitted to rig in and out. Turrets and ammunition hoists are operated by electricity or by hand.

In the German navy four dynamos have generally been installed in the larger ships. Motors have been used to run many of the auxiliaries, such as ventilators, ammunition hoists, capstans, winches, and for training guns.

The wiring of late has been left uncovered to facilitate repairs, the use of wooden scotchmen or pipes being discontinued. Mains are laid against the bulkheads and painted over, most mains being wrapped with tin or thin metal. Branch wires are loosely secured, but so that they will not hang and interfere in the passageways.

The following translation of an article upon the electrical apparatus on board the coast defense vessel *Aegir* will be found interesting, and gives the result of the trial of the electrical machinery on board that vessel:

AUXILIARY APPARATUS CONTROLLED BY ELECTRICITY.

An extensive use of electricity has been made; besides that for interior lighting, projectors, signals, and the transmitters of orders, the dynamos supply power for ten ventilators—four for the engines, four for the interior of the vessel, and two for the driers; one motor for the helm; two winches for the boats; two capstans; three sets of apparatus for training the guns; five ammunition hoists; and one compression pump for loading torpedoes.

The generating dynamos and a part of the motors have not fulfilled all that was expected of them. However, it would not do to condemn the principle, as the apparatus was made by a firm that had never before had any experience in their construction. Noticeable mistakes were made in ascertaining the required energy for certain of the apparatus, the errors being due to underestimation. In the capstans, for example, the electrical power was just sufficient to weigh anchor. It is absolutely indispensable to allow a greater margin in apparatus of this kind. The generators are governed by a steam motor, whose regulators are not sensitive enough as regards the great variations of the ampèreage.

The question of detail of the motors has also given much trouble, particularly when tried with new combinations, and it seems but right that ample time be given those having the matter in hand in order that they may familiarize themselves with the materials, which, if used properly, cannot but give the results predicted. On the other hand, the advantages of electric power are so considerable from the standpoint of incumbrance, temperature, damage, protection, etc., that its use will certainly be a grand lesson when a system is attained whose defects, now seemingly insurmountable, are overcome. The generative dynamos which supply the light and the power for the auxiliary apparatus, except the motors used in turning the turrets, are three in number, each of 400 ampères. They then give 1,200 ampères, and for the simultaneous starting of all the apparatus, including those for lighting purposes, 2,300 ampères are required.

The generators for the motors for the turrets are independent and are controlled by steam turbines, which supply their motor at a tension of 120 volts. It being certain that there never arises a necessity for working all the apparatus at once, the energy necessary is then an affair of proportion, but it is not sufficient here. Thus on the *Aegir* they cannot at the same time weigh anchor, hoist a boat, and light a projector. These, however, are the usual conditions in navigation. It seems that a better result in the actual installation could be reached by changing certain connections, but no matter what is done, three dynamos will never be sufficient for the electric plant of the *Aegir*, where at least four are needed. If to this is added the necessity of inspecting and repairing the dynamos, it will be readily seen what bad conditions exist.

The installation of the electric lighting has given no inconvenience; moldings were omitted, and it was readily found that the installations for the illuminating could be left uncovered. The search for defects is very simple, and it seems preferable to keep the illuminating material in such slight repairs as it will require from day to day to going more deeply into the subject by endeavoring to find the solution in permanent insulations. It is not well, however, to exaggerate the efficiency of the installation, which, undoubtedly, has many bad qualities. The projector circuit and the circuit for the signals are installed in this manner.

The installations for the ventilators have given excellent results.

The ventilators for the boiler room are controlled by steam motors, not solely on account of the heat, which rapidly deteriorates the insulators, but on account of the coal dust, which is a good conductor.

The motor for the steering gear worked well during four hundred and seventy-eight hours, and sustained during that time but one injury at the end of a trial. The noise of the motor, the buzzing of the conductor, and friction of the brushes is considerably less than that of a steam servo-motor; it is, however, sufficiently strong to make the transmission of orders from the bridge through the speaking tube uncertain. The naval personnel has given considerable time to this feature, but, like all new things, it will take time to get accustomed to it. The control of the motor is as yet indifferent. It is based on a contact apparatus which in running easily wears itself out and does not carry sufficient current to insure a precise working of the helm. The steering indicator, which is a sort of voltometer, works very well. The needle of the voltometer follows the movement of the helm with 1½ seconds retard. These are the best indicators that have been tried up to present. Their only inconvenience is that they can not be repaired on board. They have overcome the difficulty by supplying several interchangeable voltometer indicators.

The time necessary to work the tiller is very long, requiring 5 seconds to put the helm at 5 degrees; 7.7 seconds to put the helm at 10 degrees; 12.7 seconds to put the helm at 20 degrees; 20 seconds to put the helm at 35 degrees, and 28.7 seconds to change it from one side to the other.

The contract required as a maximum limit that the helm should be changed from one side to the other in thirty seconds. The contract is then fulfilled, but there is great inconvenience in that it requires considerable time for the first five degrees on account of casting off the motor. This is evidently a condition inferior to what was contemplated.

The board has contended that it is absolutely necessary, in case of emergency, that the working of the helm be more rapid. It further held that it was more important to devote time and attention to correctly putting the helm down in starting at "0°" than to changing it from one side to the other, and asks that hereafter it should be the contract starting point. As to the question of weight, the electric motor weighs nearly double the servo-motor that would be required.

The motors of the helm during the trial did not sustain a single damage. Nevertheless, doubts of their endurance were entertained, and no one is certain what they would accomplish after a prolonged use. In face of all these good reasons the board contended that it was indispensable to have steam servo-motors to overcome defects in the electric order until it was certain that the working of the same for some length of time could be conducted satisfactorily.

The boat winches fulfill the conditions of the contract, and hoist the boat at a speed of 10 meters per minute. In this, however, the electric motors are inferior. The casting off is always slow, and it was found that during the first fifteen seconds the speed was not more than 1.6 meters, while with a steam winch it was 2.5 meters. This consideration is of great importance in hoisting the boats in bad weather.

The motors for the capstans are entirely too weak, it being impossible to weigh anchor with a single motor. Undoubtedly the anchor and chain could be hauled up, but never weighed. If they couple the motors, they are hardly sufficient to weigh the anchors at 40 meters depth. It would require motors of double that power in order that one of them could weigh anchor under average conditions, and a second one would not have to contribute except under unfavorable conditions owing to bad weather. The board concluded by imperatively demanding a steam motor for the capstans.

* * * * * * *

It would not yet be well to give a definite opinion upon the electric apparatus for training the guns, which make, nevertheless, much noise and renders hearing difficult in the turret. This noise could doubtless be lessened by inclosing the apparatus in a sort of covering. The motors have otherwise fulfilled the conditions of time and power required by the contract.

The trials of the ammunition hoists have been satisfactory.

The question of the precision of the electric brake at the end of the course has been answered. The question arises, however, why the same type of ammunition hoists which gave admirable results on board the *Kaiser Augusta* were not installed on board the *Ægir*. It seems that the electric motors are particularly suitable to this kind of ammunition hoists.

The motors that control the compression pumps have also given excellent results, even to an extent in favor of the electric motors, which adapt themselves easily to great speed.

The electric transmitters for orders have been mediocre. Numerous mistakes have arisen; either the incandescent lamp did not light or else several lamps lighted at the same time. This system should be condemned. The compass was observed with great care during the working of the electric motors. It was not possible to determine the deviations due to the circuit current. They are, however, slight, since the effect of the current is counterbalanced by that of the return current. * * *

It has been decided to use motors largely in the Italian navy for auxiliaries, not only in their new but in their old vessels, which will necessitate changes in the distribution by special circuits to the switchboard system allowing the dynamos to be run in parallel.

The *Saint Bon*, one of the latest ships, has four generating sets of 300 ampères each, and arrangements have been made for five in case of necessity. A voltage of 110 is used.

The mains are of uncovered copper wire, insulated by porcelain and carried in iron pipes. Branch circuits will be lead covered, and no moldings used.

Russia has taken the lead in using electrical auxiliaries. In her recent battle ships and large cruisers, four generating sets have been placed below the protective deck and two sets above. A pressure of 105 volts is used. It is intended to use motors to run the following auxiliaries: Windlasses, capstans, ammunition hoists, blowers for hull, engine and fire rooms, machine shops, turret rammers, training gear for turrets, draining turbines, elevating gear and training gear for guns, boat cranes, pumps, and steering gear. Seventy to eighty motors will be required for these auxiliaries in their larger vessels. The wiring will be uncovered, and 1,000 to 1,500 lights installed.

Japan has followed the Admiralty methods in the installation of electric plants in her ships being built in England, but she has made a much more extensive use of motors for driving the auxiliaries than that customary in English ships.

Austria has also experimented in the use of motors for driving auxiliaries, but has not extended this manner of distribution beyond ammunition hoists, blowers, and elevating and training guns.

The general methods of installation of electrical plants in the British Navy, compared with those of other navies, is illustrated in the following article read by Mr. C. E. Grove before the Institution of Electrical Engineers, and a synopsis of the article is published for use as reference for the officers of the service:

THE ELECTRICAL EQUIPMENT OF SHIPS OF WAR.

INTRODUCTORY.

This subject, already a great one, is rapidly growing, and the use of electricity on ships of war is yearly being extended in all the navies of the world. While, therefore, the bulk of the paper records what has already been accomplished, regard has been paid throughout to certain imminent developments which in many departments overshadow present day practice.

The methods followed in the English navy have to so large an extent constituted a guide and pattern to the world that the basis of the present paper lies naturally in British Admiralty practice. In certain navies, however, important departures from British practice now exist, and tend to become more marked with the flux of time. Some of these are referred to hereafter. The author's intention has been entirely to avoid administrative and tactical questions, and to treat the subject solely from the point of view of an independent electrical engineer. In British warships and in ships built in this country for foreign Governments the constructive work falls into three main divisions, dealt with respectively by the "shipbuilders," the "engineers," and the "ordnance contractors;" and part of the electrical work falls into each division. In the present paper this distinction is ignored and the electrical equipment treated as a unity.

PART I.—GENERAL EQUIPMENT.

DYNAMOS.

The first important step in the use of electricity on board ships of war dates from the introduction of the dynamo. In 1876 a Wilde alternate-current magneto machine, belt-driven, was installed in H. M. S. *Minotaur* to work a searchlight projector. This machine gave place to the continuous-current Gramme dynamo, so soon as the latter had assumed practical form; and this again was superseded in due course by the two-pole drum-wound direct-coupled compound steam dynamo, which until about 1895 was standard in our navy. The size of unit varies in our navy by steps of 100 ampères from a machine giving 100 ampères in the case of torpedo-boat destroyers, small gunboats, and the like, to a machine of 600 ampères, as now used in all modern battleships and large cruisers. The standard voltage is 80 in all cases, this having been settled long ago as a convenient compromise between the pressure required for working searchlights and that giving the best efficiency in the ordinary electric-light circuits. With the growing demands for current, this low voltage is becoming increasingly inconvenient—a matter which will be referred to again farther on. For all sized sets, from 200 ampères upward, the standard speed is 300 to 320 revolutions per minute, though in the smallest sets speeds occasionally run up as high as 500 revolutions per minute. Engines running up to 500 revolutions with forced lubrication are now being introduced for the larger sizes. By the provision of clauses in the specification requiring the engine to work the dynamo with a low steam consumption, and requiring that the temperature of the dynamo after six hours' run at full load shall not exceed 80° F. above the surrounding air, the essential conditions for obtaining a well-built machine of high efficiency and moderate weight are secured. Fig. 1 shows the general appearance of a British Admiralty steam dynamo of the ordinary two-pole horseshoe type. These machines almost invariably had smooth cores. "Ironclad" machines were introduced some five years ago to overcome a difficulty which had been discovered on ships equipped with ordinary dynamos, namely, that considerable disturbance of the compass readings was observed, depending on the stray magnetic field produced by the dynamos and varying with the number of dynamos that were at work. Until this interference had been actually proved to be due to the dynamos themselves, it had been attributed to induction from the currents in the wires about the ship; but it was found that their action was much less important than the direct influence of the dynamos. With an ironclad machine the stray magnetic field is reduced to one-half, or less, of what it is with an ordinary open-type machine, the stray field from the magnets (provided the machine is liberally designed as regards the mass of iron) being almost nil, while the leakage of magnetism axially along the armature shaft is greater.

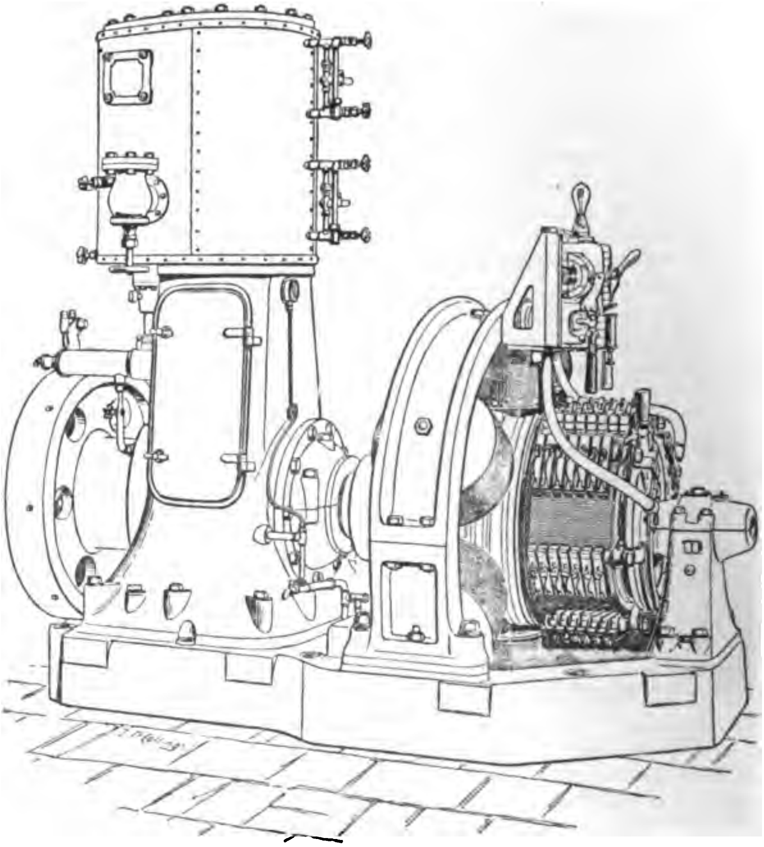


Fig. 5.—United States Navy generator, 50 k. w. (General Electric Company).

The chief difficulties in designing ironclad dynamos arise in designing to a minimum weight and in providing adequate ventilation. Figs. 2 and 3 show an ironclad dynamo of the author's design in which thorough ventilation is secured by the device of coring slots through the bottom, sides, and ends of the magnet castings. The

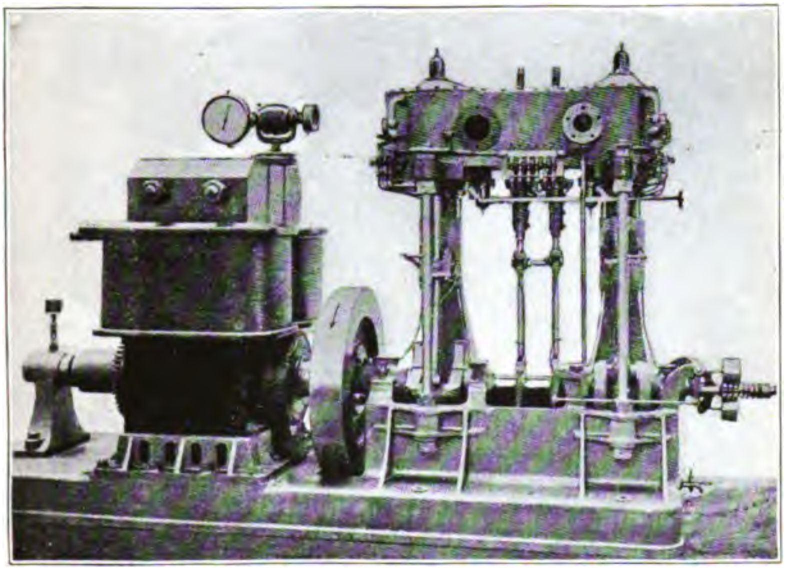
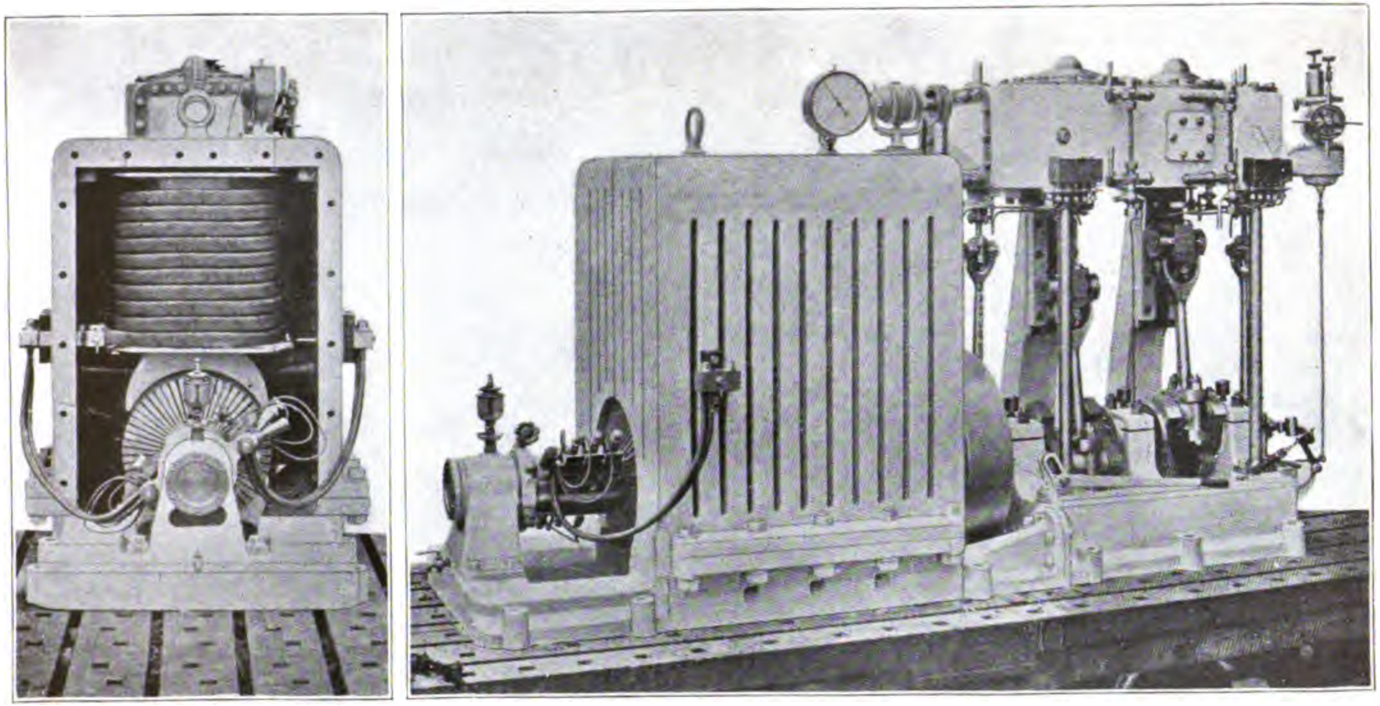


Fig. 1.—ADMIRALTY PATTERN 2-POLE STEAM DYNAMO.

(Siemens dynamo and Thornycroft engine.)



Figs. 2, 3.—"IRONCLAD" DYNAMO.

(Thames Iron Works.)

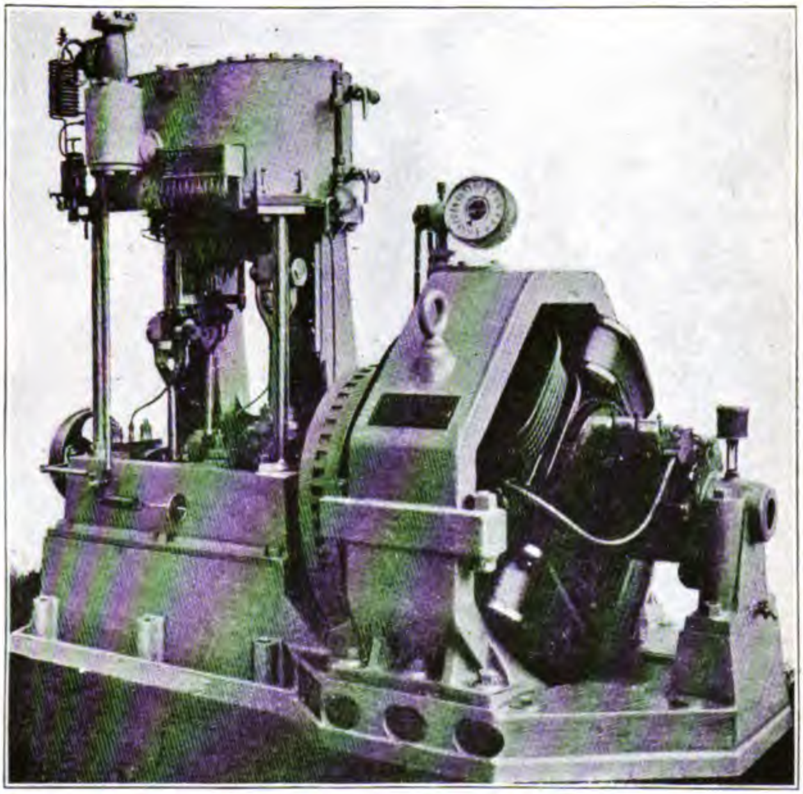


Fig. 4.—MODERN ADMIRALTY MULTIPOLAR GENERATOR.

(W. H. Allen, Son & Co)

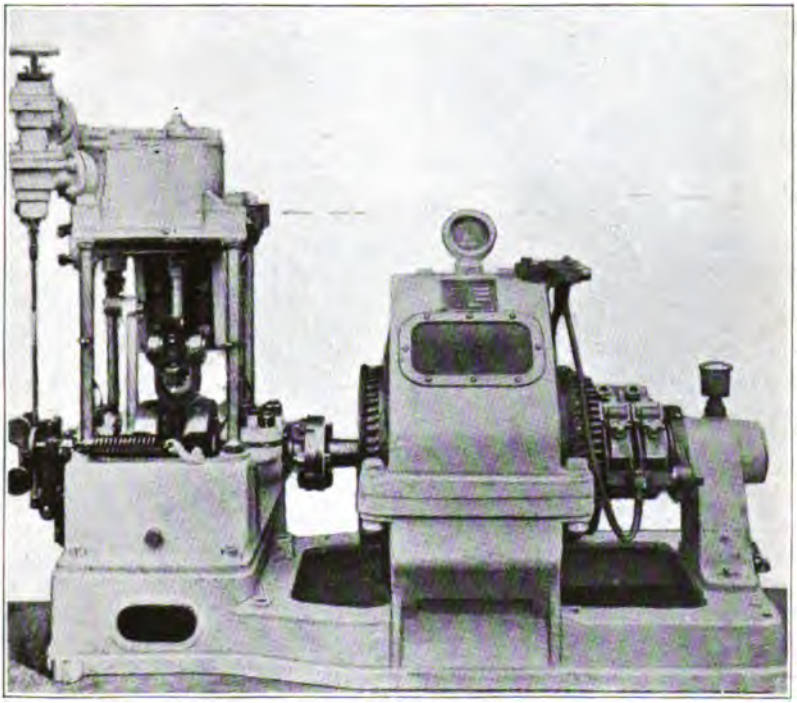


Fig. 6.—VEDETTE BOAT STEAM DYNAMO, 6 K. W.

(Thames Iron Works.)

weight of an ironclad dynamo is greater by 50 per cent to 75 per cent than that of an ordinary Admiralty open-type machine of the same output, which reason has led to the ironclad type being superseded by an open four or six pole machine, which, on the whole, provides the best combination of good ventilation, minimum external leakage, and accessibility of parts. Fig. 4 shows a recent 600-ampère admiralty set, by Messrs. W. H. Allen, Son & Co. Most modern Admiralty dynamos have slotted cores. The total weight of such a set is about 6½ tons, of which the armature represents about 1½ tons.

The United States Navy usually employs a four-pole machine, their largest units being of 50 kilowatts at 80 volts at 400 revolutions per minute. The temperature limit is however 50° F., which involves a heavier dynamo than the British for the same output. Fig. 5 shows such a set, constructed by the General Electric Company of Schenectady.

By way of contrast to these large machines, a small steam dynamo (fig. 6) may be mentioned, which was recently designed by the author and fitted into 40-foot and 56-foot steam pinnaces for the Russian Government for working searchlights. In this particular case the required output was 60 ampères × 65 volts at 500 revolutions per minute, though the set has a maximum output of 6 units, on a total weight of 12 cwt.

Steam engines of the open type are usually employed for dynamo driving. They have to be constructed strongly enough to work with the full steam pressure from Belleville boilers (275 to 300 pounds per square inch), though with cylinder areas large enough to furnish their nominal full output at 150 to 200 pounds pressure. Among the essential conditions for successful working are ample bearing surfaces, with thorough lubrication, to insure cool working for long periods, and ability to get rid of large volumes of water, which come over with the steam when auxiliaries on the same range of steam pipes are started.

The importance of preserving the dynamos unharmed in war is so great that at least a sufficient number of sets to supply all the fighting parts of the ship must be kept under protection. Unfortunately this generally means placing the machines in a warm, ill-ventilated space, so that their durability is impaired. Again, if all the dynamos are together, an injury to the compartment, or to the steam and exhaust pipes serving the electric-light engines would place the whole hors de combat and put the ship in darkness. Our Admiralty practice is to put one of a set of three or four dynamos in some daylight position on the upper or main deck to supply all the ordinary lighting current in "peace," and to place the dynamos that are used in action below the water line. Nations differ as to the advisability of doing this, the control being certainly less convenient when the machines are in separate places. The United States Navy places all the dynamos in one compartment. The Japanese divide the dynamos between the fore and aft auxiliary machinery rooms, but keep them all under protection.

SWITCHBOARDS.

This standard British Admiralty pattern switchboard consists of a slate or slates carrying horizontally upon them a series of omnibus bars, connected severally with the positive and negative terminals of the dynamos; and bridging over these, a series of vertical slotted bars leading through fuses to the circuits, and carrying sliding contact plugs which can be pressed down so as to make contact on the top and sides of the omnibus bars, being locked in the "on" position by a spring handle, and maintained in the "off" position by the action of an internal spiral spring, which also gives a quick break. The switchboard has the merit that all the current-carrying parts are on its face, and it is fairly compact; but the method of making electrical contact leaves much to be desired, and the switch parts consist of a number of components which give complexity and add to the cost of maintenance. The present design of board grew out of that older type known to telegraph engineers as the

"Umschalter," in which contact was made between any one of a series of vertical bars and any other of a series of horizontal bars by screwed or coned plugs uniting them at their intersection; this style of board failed in service because of the practice of making and breaking circuit on the plugs, which led to their speedy destruction.

In the English Admiralty board, while any circuit or any number of circuits can be worked from one dynamo, it is not possible to work two or more dynamos in parallel on the same circuit; and in transferring a circuit of lights from one machine to another, it is necessary to extinguish them during the process, which is objectionable. Time was when the parallel working of compound-wound dynamos was attended with difficulty; but the conditions are now well understood, and parallel working is, in fact, in successful operation on many ocean liners and in other navies.

These switch boards are usually made up to standard drawings and arranged for three dynamos and six circuits. When, as is commonly the case, the number of circuits exceeds six, one or more additional boards are fitted, and their dynamo bars coupled. Fig. 7 gives a view of three such boards coupled in position on the Japanese battleship *Shikishima*, which carries three 600-ampère dynamos and eighteen circuits, six circuits supplying incandescent lights, four projectors, and the remaining eight motors.

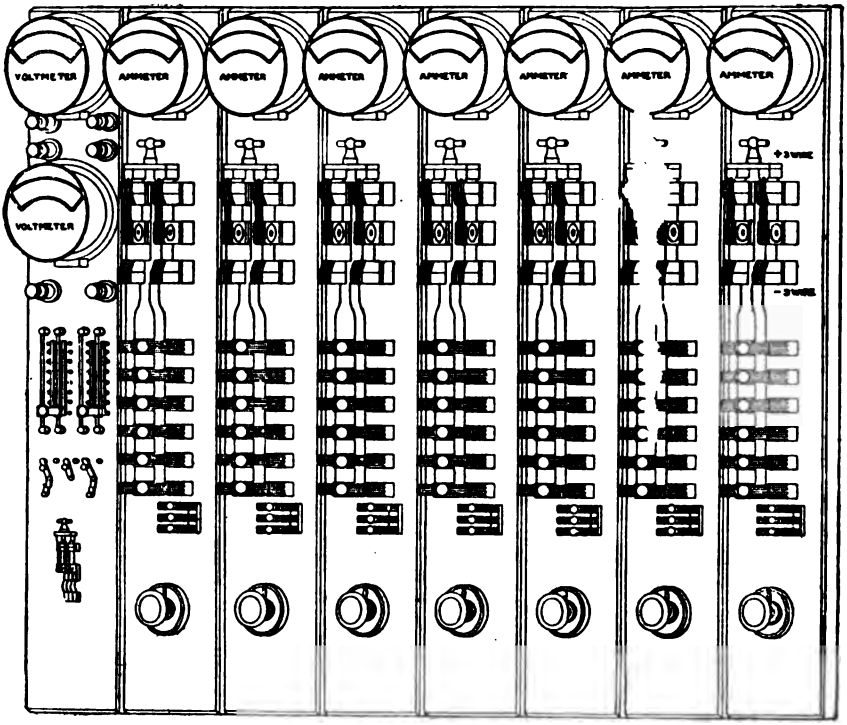


FIG. 8.—Main generator switchboard U. S. S. *Kearsarge* and *Kentucky*.

The battleships of the *Formidable*, *Duncan*, and more recent classes and the cruisers of the *Drake* class will carry four 600-ampère dynamos, usually running at 400 revolutions per minute, and a large number of circuits, some of which will supply current to powerful motors. The design of switch board described above appears to be quite unsuitable for such installations.

The Cardew hot-wire voltmeter and the Siemens torsion spring ammeter are the instruments chiefly to be found on H. M. ships, though these are no longer standard,

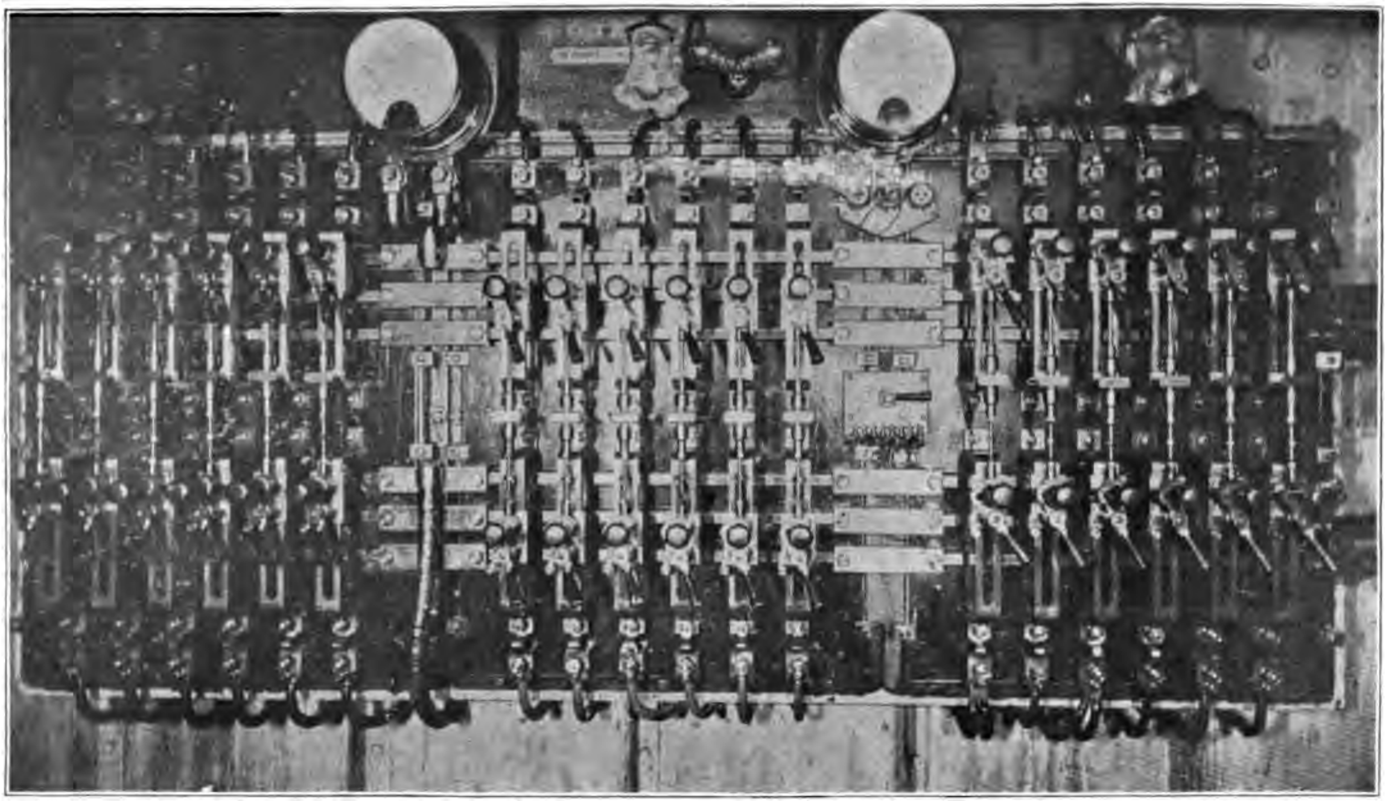


Fig. 7 —ADMIRALTY-PATTERN SWITCHBOARDS, AS FITTED IN H. I. J M. S. SHIKISHIMA.

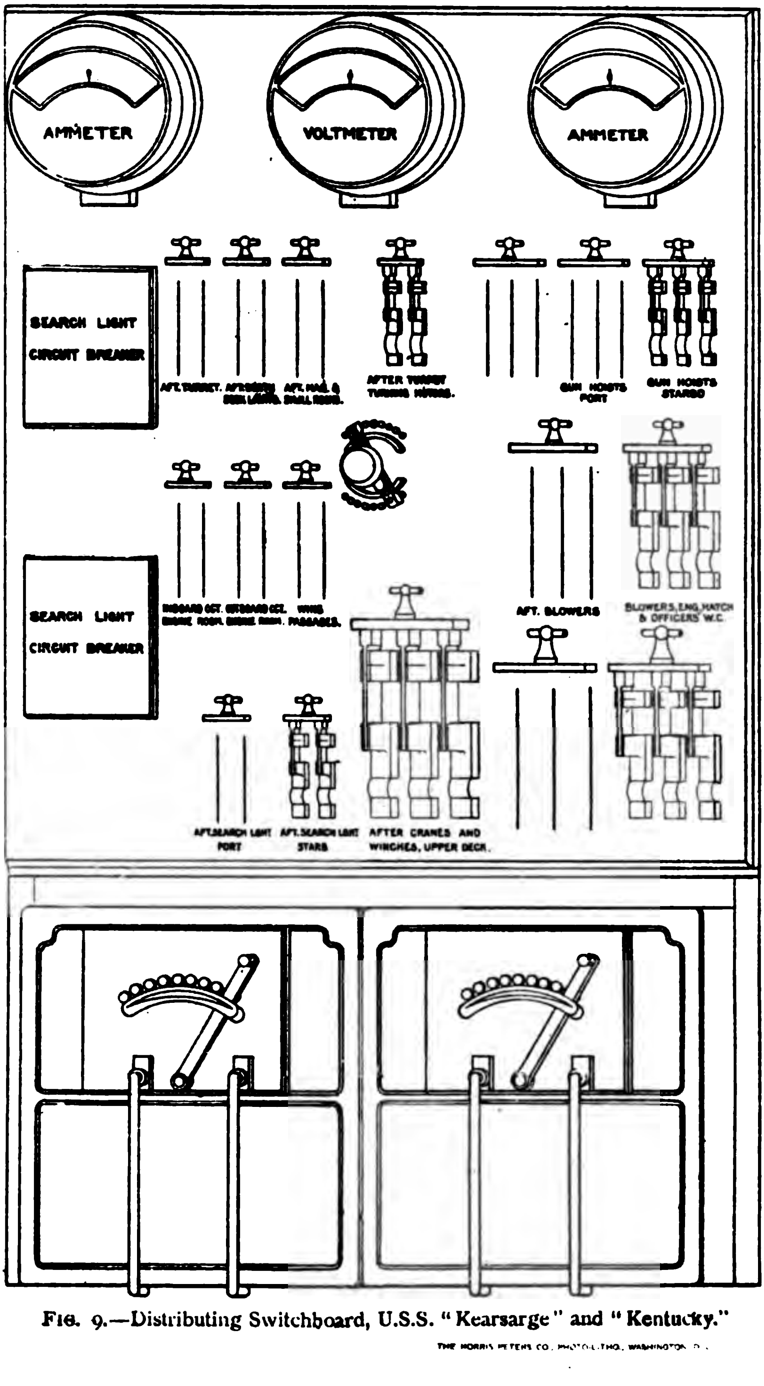

AMMETER
VOLTMETER
AMMETER
SEARCH LIGHT CIRCUIT BREAKER
AFT. TURRET.
AFT. BERTH DECK LIGHTS.
AFT. HALL & SMALL ROOMS.
AFTER TURRET TURNING MOTORS.
GUN HOISTS PORT
GUN HOISTS STARBD
SEARCH LIGHT CIRCUIT BREAKER
INBOARD OCT. ENGINE ROOM.
OUTBOARD OCT. ENGINE ROOM.
WING PASSAGES.
AFT. BLOWERS
BLOWERS, ENG. HATCH & OFFICERS' W.C.
AFT. SEARCH LIGHT PORT
AFT. SEARCH LIGHT STARB
AFTER CRANES AND WINCHES, UPPER DECK.

FIG. 9.—Distributing Switchboard, U.S.S. "Kearsarge" and "Kentucky."

THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

having been replaced by dial instruments of the well-known Evershed pattern. The instruments are usually placed in close proximity to the dynamos and not upon the switch board. Circuit breakers are not used in the dynamo circuits of our navy, though double-pole fuses are now generally fitted in the machine leads.

The United States Navy standard switch board is planned with its dynamo bars vertical and circuit connections horizontal, and is designed for parallel working. Fig. 8 shows the main generator board fitted in the recent battleships *Kearsarge* and *Kentucky*, which each carry seven 50 k. w. dynamos. Each dynamo bar is surmounted by its ammeter and main throw-over switch. A panel at one end contains the instruments used in common by all the dynamos. The field terminals of the machines are brought to the switch board, where they may be connected either for self or separate excitation. Equalizer switches are fitted on a separate panel in another part of the room.

From the main board feeders are run to three 3-wire main distributing boards (fig. 9) located respectively forward, aft, and amidships, from which the several power, searchlight, and lighting circuits are run. Each of these boards receives from the main generator board five cables, a pair of "outers" for lighting, a similar pair for power, and a common neutral. Four subdistribution boards for groups of motors are supplied from the main distribution boards.

A circuit breaker and a short-circuiting switch for the series winding are carried by each generator on the terminal board, from which its main cables are led (fig. 5).

The electrical principles involved in this scheme of connections seem, in the main, right; but the multiplication of switch boards is a bad feature, which is said to have been necessitated by restrictions of space in the ship.

ELECTRIC LIGHTING.

The first installation of electric lamps on a war ship was put in H. M. S. *Inflexible* in 1881. It consisted of a set of arc lamps run in series from a Brush dynamo with glow lamps arranged, 18 in series, on the high-tension mains. The arc light has disappeared. Modern war vessels are usually too much subdivided and have too little head room to justify the use of arc lamps, although these are again becoming somewhat common on merchant vessels. The parallel glow-lamp system became standard practice almost as soon as it was introduced, and the number of lamps employed has been steadily increasing. Thus, in the battleship *Colossus*, fitted in 1884, 350 lights were installed; in the *Blenheim*, first-class cruiser, fitted in 1890, 525 lights were installed; the *Majestic* class of battleships, fitted in 1896, carry between 800 and 900 lamps; the *Albion* and her sister battleships of the *Canopus* class, just completing, carry about 950; the *London* and *Duncan* classes of battleships now building will carry from 1,000 to 1,050 lamps, while the first-class cruisers of the *Drake* and *Monmouth* classes now building will carry approximately 1,000.

It is usual to arrange the electric lamps in six circuits, one circuit being exclusively devoted to engine and boiler rooms, one to magazines, one to the central citadel, one to the crew spaces forward, one to the cabin spaces aft, and one to the stores and machinery rooms below the belt deck. It is desirable to have separate circuits for those portions of the ship which are protected by armor, rather than to mix up the lighting of protected and unprotected portions, though this is by no means generally done. A schedule showing the arrangement of lamps, fittings, and circuits on H. M. S. *Albion* is given in fig. 10. In the United States Navy the lamps are arranged on two main circuits, known respectively as the "battle" circuit, which includes the lighting of all parts of the ship occupied in action, and the "lighting" circuit, which includes those parts where general illumination is required for ordinary purposes. Feeders running from the switch boards connect to the respective circuit networks through junction boxes. At "general quarters" the ordinary lighting circuits, which include all the exposed lights on the upper decks, are disconnected at the switch boards. This arrangement prevents stray light shining outboard.

Lead-covered cables and wires, first introduced into the Japanese cruiser *Naniwa-Kan*, built at Elswick, are universally used in our navy, and the insulation is now vulcanized india rubber in all cases. For single lamps a pair of 1/16 wires are employed; stranded wires which group the sets of lamps through fuse boxes up to the circuits are universally composed of multiples of single 20-wire, the standard sizes being 7/20, 11/20, 15/20, 30/20, 60/20, 80/20, and 150/20, while for dynamos and heavy motor circuits 350/20 and 550/20 are employed. The current density is usually a little below 1,000 ampères per spuare inch, which insures in the lengths dealt with a very moderate voltage drop. The present mode of fixing the wires and cables is to attach battens of teak to the bulkheads and to run the wires side by side along the teak under brass cleats or saddles. Thus all the wires are visible. According to Admiralty specifications, steel battens may be used as an alternative to teak, but they would be much heavier, and the author is not aware of any ships so fitted. The introduction of these teak battens into our navy took place but a few years ago, and the step appears to have been quite a retrograde one. The employment of wood allows of

Decks.	Fittings.															Circuits.					
	Circuits.	Bulkhead.	Pendt. guard'd.	Brackt. guard'd.	Pendt. cabin.	Brackt. cabin.	Pendt. special.	Hand.	Table.	Bunker.	Pedestal.	Signals.	Pilot.	Magazine.	Yardarm.	Total fittings.	Forward.	Midship.	After.	Store.	Engine room.	Magazine.
Above bridge.	Aft	...	...	...	...	...	...	1	...	...	...	1	...	...	8	...	...	...	10	...	...	...
	Ford	...	...	...	...	...	...	1	...	...	...	9	...	...	8	...	18	...	...	...	...	...
Bridge	Aft	3	2	...	2	...	...	3	...	...	3	...	...	...	...	...	...	...	13	...	...	...
	Mid	...	...	...	...	...	...	...	...	...	3	...	...	...	...	...	...	3	...	...	...	...
	Ford	3	2	...	2	...	...	...	...	...	5	2	...	...	...	...	14	...	...	...	...	...
Upper	Aft	...	8	8	5	2	...	2	2	...	...	...	...	...	...	...	...	...	27	...	...	...
	Mid	...	28	...	...	...	...	...	...	...	...	...	...	...	...	...	...	28	...	...	...	...
	Ford	...	10	9	...	...	...	1	...	...	...	...	...	...	...	...	20	...	...	...	...	...
	Eng	...	...	11	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	11	...
Main	Aft	...	18	1	27	19	...	...	12	...	...	...	...	...	...	...	...	...	77	...	...	...
	Mid	36	35	6	...	...	...	2	...	...	...	...	...	...	...	...	...	79	...	...	...	...
	Ford	15	10	5	5	...	...	...	1	...	...	...	...	...	...	...	36	...	...	...	...	...
	Eng	...	...	12	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	12	...
Middle	Aft	...	14	9	6	23	...	...	...	...	...	...	...	...	...	...	...	...	52	...	...	...
	Mid	18	22	1	...	...	...	...	...	19	...	...	...	...	...	...	...	60	...	...	...	...
	Ford	19	7	11	...	...	...	...	...	...	...	...	...	3	...	...	40	...	...	...	...	...
	Eng	...	...	11	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	12	...
Lower	Ford	1	2	...	...	...	2	2	...	...	...	...	...	...	...	...	7	...	...	...	...	...
	Store	5	42	25	...	...	8	10	1	...	...	...	...	...	...	...	...	...	...	91	...	...
	Eng	2	9	26	...	...	...	8	...	14	...	...	...	...	...	...	...	...	...	...	59	...
Platform	Store	2	32	18	...	...	1	13	...	...	...	...	...	...	...	...	...	...	...	61	...	...
	Eng	6	27	52	...	...	...	2	...	...	...	...	2	...	...	...	...	...	...	...	89	...
	Mag	...	...	...	...	...	...	...	...	...	...	...	...	44	...	...	...	...	...	...	...	44
Hold	Store	...	4	...	...	...	6	...	...	...	...	...	...	6	...	...	...	...	...	16	...	...
	Eng	...	6	2	...	...	...	2	...	...	...	...	...	...	...	...	...	...	...	...	10	...
	Mag	...	...	...	...	...	...	...	...	...	...	...	...	38	...	...	...	...	...	...	...	38
Totals	...	110	278	202	47	44	17	47	16	33	11	12	3	91	16	927	135	170	179	168	193	82

FIG. 10.—Schedule of electric lighting, H. M. S. *Albion*.

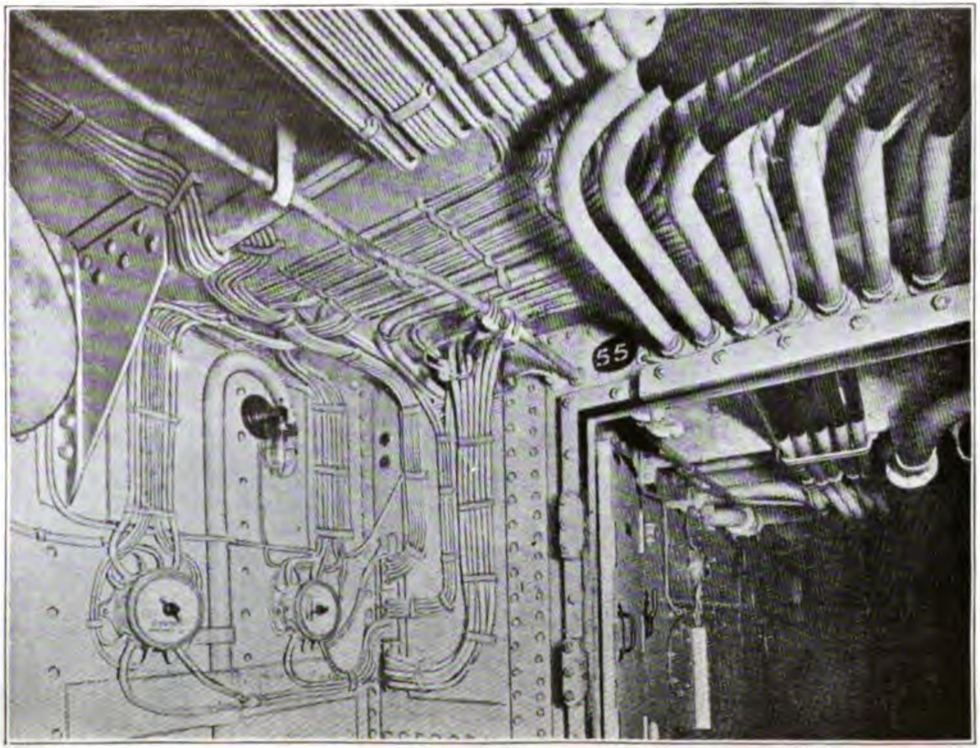


Fig. 11.—CABLE WORK AT ENTRANCE TO AN AMMUNITION PASSAGE, SHOWING PLATE WATER-TIGHT GLANDS.

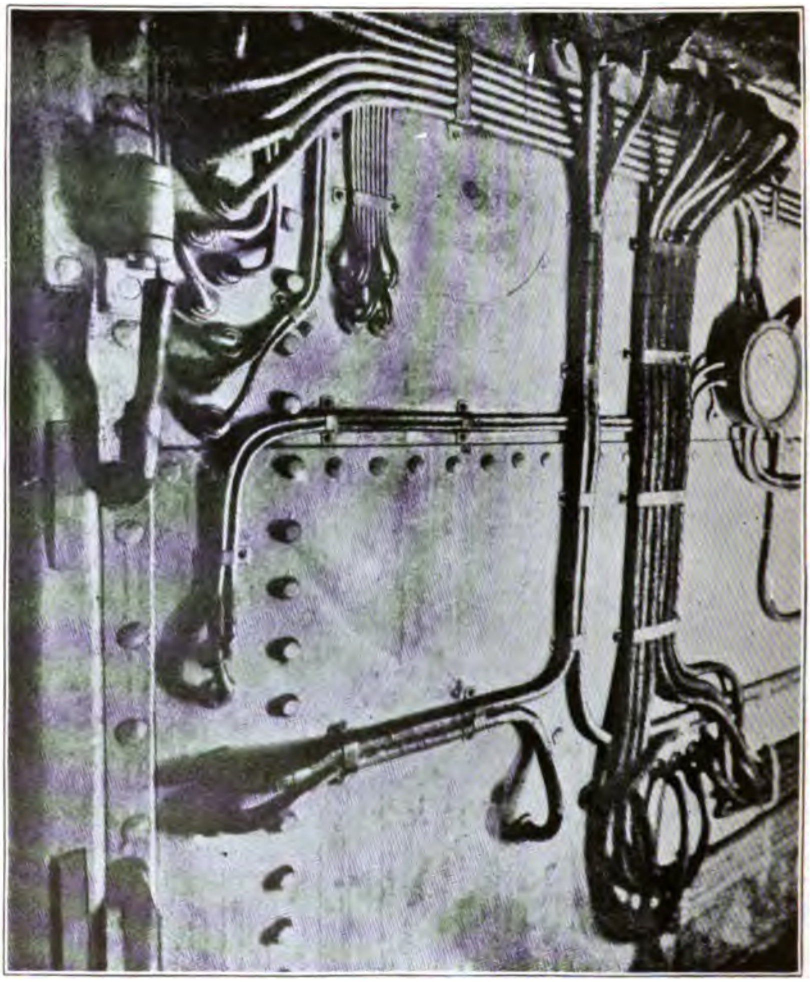


Fig. 11*a*.—CABLE WORK BEHIND SWITCHBOARD, SHOWING TUBULAR WATER-TIGHT GLANDS.

fewer holes being drilled in decks and bulkheads than would be otherwise necessary, but the aggregate cost of the wiring work is considerably enhanced, useless weight is worked into the ship, and the danger of fire increased. The Japanese have in their latest battleships had the cables and wires attached directly to the decks and bulkheads, dispensing with backings, except where necessary for the heaviest runs or as packing to carry heavy runs of the larger cables over obstructions, such as flanges of angle bars, rows of rivet heads, and the like. This makes a very substantial and satisfactory job. The practice in the United States Navy very much resembles land practice. Lead-covered wires were employed at one time, but it is said that the quality of the lead and of the insulation was such as to give trouble, and to cause them to revert to the old system. In their latest ships they have run braided wires in wood moldings in cabin spaces and in iron pipe or conduit in machinery spaces, while in the crew'spaces and in some of the fore-and-aft runs the wires are supported below the decks on porcelain insulators, and protected by thin iron guard plates put over them. None of these methods appears to be so safe or so thorough as the British Admiralty method of lead-covered cables closely packed together and visible and accessible throughout their length.

WATER-TIGHT WORK.

Where the wires go through water-tight bulkheads or decks, of course the bulkheads and decks must be made water-tight behind them. Until recently the method of making the cables water-tight at the decks consisted in providing a length of iron tube lined with fiber, with a stuffing box and gland at the top end, by means of which an india-rubber packing was screwed down upon the cable, and similar glands were used where the cables passed through bulkheads. One disadvantage of this arrangement was that where a number of cables and wires had to be dealt with, a considerable amount of space was taken up by these pipes in order to provide room for spanners to work in tightening up the nuts. A simple, compact, and effective method is as follows: Two pieces of wrought-iron plate are drilled with holes slightly larger than the size of the cables that are to go through the bulkhead; similar blocks of india rubber, about half an inch thick, have holes formed in them just the neat size of the cable; the bulkhead is drilled with clearing holes; a slab of rubber and an iron plate are placed on either side of the bulkhead, the cables are drawn through, and then the plates screwed up tight. By this means pressure is put upon the rubber, which tends to make the holes through which the cables pass smaller, so that the cables are griped, and the holes are left water-tight. This arrangement was used by the author throughout the Japanese battleship *Fuji*, both for decks and bulkheads. Fig. 11 shows a grouping of cables through such glands at the water-tight bulkhead alongside the entrance of an ammunition passage. Many ships fitted at Portsmouth have rubber-packed plate glands, though these are fitted only on one side of the bulkhead.

A new arrangement (fig. 11A) was introduced by the British Admiralty in 1898. Brass glands of tubular form, screwed to take a nut at one end and having central holes, previously tinned, about one-eighth inch larger in diameter than the cable intended to pass through, are inserted in the bulkheads and made water-tight on the iron by means of red lead. The lead-covered cable is drawn through and its tape stripped back to bare the lead at the gland, a split tinned ferrule is then inserted to fill the clearance space around the cable, and the whole is then sweated up solid by means of a blowpipe. This is a rather tedious method until the men get accustomed to it, and there is some danger of overheating the insulation unless care is used. Once the cables are tightly drawn through and sweated up, they have a neat and solid appearance, but they can not be drawn back, and when repairs become necessary it seems likely that the cables will have to be cut, which is a great disadvantage.

The main-circuit cables from the switch board pass, in the case of the heaviest circuits, through "junction boxes," into which they split usually into two branches protected by fuses. Each of these branches then passes through a series of "section boxes," which are circular water-tight boxes containing a switch and four pairs of terminals for the attachment of fuses and the branching of cables. Each of the four pairs of cables running from a section box terminates in a "distributing box," which is a similar box to the section box and contains fuses and a double-pole switch.

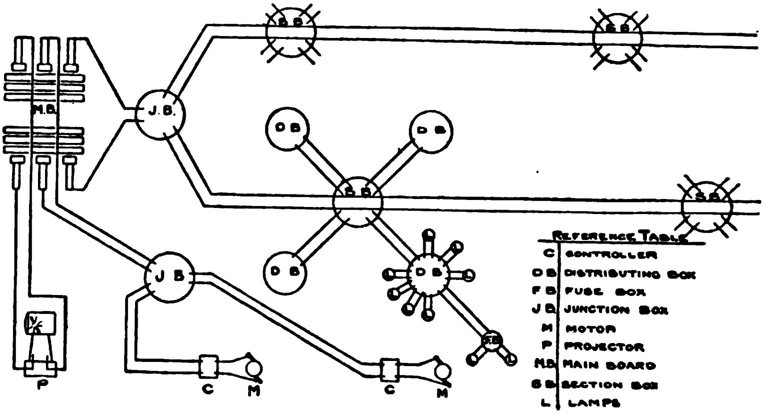


FIG. 12.—Diagram of Admiralty distributing system.

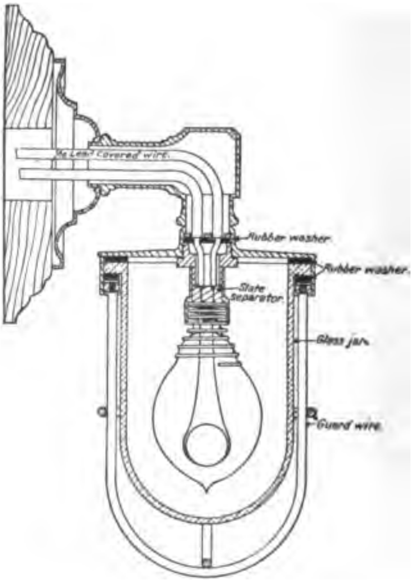


FIG. 13—Admiralty pattern water-tight bracket.

From each distributing box eight pairs of wires are taken, each pair leading direct to the terminals of one lamp. Fig. 12 illustrates the arrangement. As explained in the next section, no lamp holders, properly speaking, are employed. This "distributing-box system" was introduced into British warships about 1892. It is a modification of a method previously developed and used in wiring hotels, blocks of mansions, and such like places. Its advantages are that it enables the electric-light system to be entirely laid out without any joints or branches in wires, thus dispensing at once with what is usually an important source of trouble. In the event of any part of the system becoming injured it can at once be switched off at the nearest distributing or section box, and the working of the system in general is not interfered with. The system allows of the work being rendered more completely water-tight than could otherwise be accomplished. The lead covering of the wires is stripped back sufficiently to enable the wires to enter the terminals in the box; the lead is then sweated to gland plates, which are made water-tight with red-lead packing. While there are no single-light fuses employed except in distributing boxes, it is usual to employ single-light switches placed close to the fittings for all lights except those in crew spaces and magazines, which are controlled in groups.

Double-wire lighting circuits are universal. H. M. S. *Polyphemus* was the only British ship in which single wiring was employed, and this was soon converted. Concentric systems, with or without the outer conductor earthed, have been frequently advocated for war ships, but they do not lend themselves so readily to the repair of small injuries as the twin-wire circuits employed.

FITTINGS.

Fig. 13 illustrates a typical Admiralty water-tight fitting, showing the method of wiring. The lead-covered wires are drawn through an india-rubber washer pierced with two holes, which fits tightly into the neck of the fitting, thus excluding moisture; the lead and the insulation are then stripped back, and the bare wires led through holes in a slate disk which forms a separator; no lamp holder, properly speaking, is used, but the ends of the wires are turned back with pliers to form hooks, and on to these bottom loop lamps, having twisted spiral platinum loops, are hung. Loop lamps are used because they best stand vibration and shock due to gun fire. But this method of wiring is capable of considerable improvement. If the hooks in the wires are not properly formed and are not of exactly the right length, bad contact and sparking result, and the wires are burnt. If from any reason the hooks get injured or broken off, little pieces of wire have to be soldered on, which is not good. It would be much more satisfactory if the wires terminated in fixed contact blocks, and the fitting, wired complete and provided with spring-contact plungers, were then independently attached. In the *Shikishima*, combination fittings, carrying electric lamps and candles, were wired in this way by the author with success, the removal of four fixing screws allowing the fitting to be bodily taken away without disturbing the main wiring.

SIGNAL LIGHTS.

Every ship, of course, carries the ordinary international navigation lights, port side red, starboard side green, and masthead white, which must be alight all the while the vessel is under way, together with white riding lights, which have to burn when the ship is at anchor. In British ships, co-called "position lanterns," two in number, are carried on the ensign staff when at anchor. In order to provide against failure of the navigating lights, the lanterns sometimes contain two lamps with an automatic switch for throwing the second into circuit if the first fails. This does not, however, make a good arrangement, because both lamps can not be placed in the focus on the Fresnel lens, and if one is right the other one must be out of position. Telltale alarms (of which there are several kinds) are used on some ships to give warning if one of the navigating lights fails. Fig. 14 shows the arrangement devised by the author for the *Fuji* and *Shikishima*. An electric bell is provided with a relay wound to one-tenth of an ohm and carrying the full current of the 50-candlepower lamp employed, say 2½ ampères. This relay magnet holds a spring contact out of connection with the bell circuit while the lamp current is on. On the failure of the lamp current, the spring contact completes the bell circuit, and the bell rings continuously. A duplex switch in one water-tight case switches both lamp and bell circuit on together. A plug connection is attached near the lamp position, so that the lamp can be removed without disturbing the wiring. The bell circuit can be tested by merely switching on with this plug connection out, when, of course, the bell will ring if all is in order.

The Ardois lantern is largely used abroad for speed signaling. This lantern, shown in fig. 15, is really a double lantern, one-half having a white Fresnel lens and the other a ruby lens, each inclosing a 50-candlepower lamp. As used by the Japanese, the lantern is hung over a sheave from the fore starboard yardarm, this sheave being surmounted by a single lantern of similar design showing a white light. When the white light in the movable lantern is shown burning close up to the fixed light it means "full speed ahead," while the red light in this position indicates "full speed astern." If the white light is shown halfway between yardarm and rail it means "half speed ahead," a red light in the same position indicating "half speed astern." When the movable light is shown quite low down, it means "slow speed ahead," and the red light in the same position "slow speed astern." The white lenses are slightly obscured because it is thus more easy to see the two separate lights when close together than if clear glasses are used. Two white lights and a central red one, in lanterns on the afterbridge rail, are used for the same purpose, and screened so that the light shows only astern.

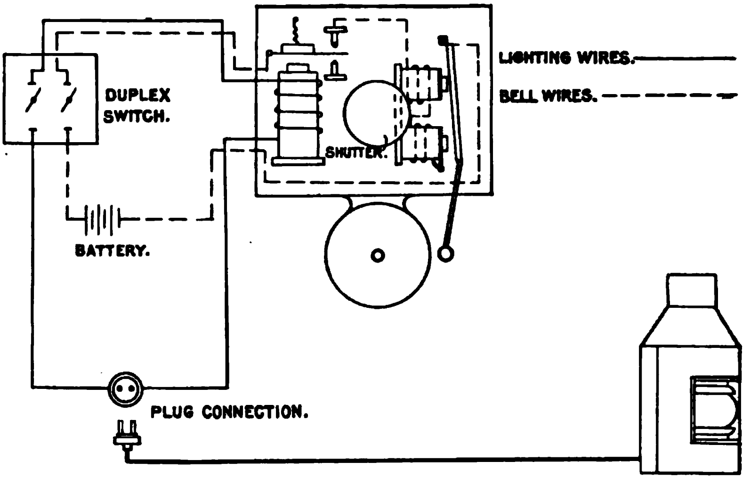


Fig. 14.—Navigation lights alarm, *Fuji* and *Shikishima*.

Among minor signals may be mentioned that employed to indicate "Admiral aboard." On British ships, three lamps are hung, respectively, at the ends and center of the afterbridge rail, and one from the military top; on Japanese vessels three lamps are hung in triangular fashion from the after military top. The same three lanterns hung in various positions are used by the Japanese for other signals.

For general fleet signaling, flashing lamps carried at the truck of the foremast are in fairly general use. They are designed so that any communication can be effected by the use of the ordinary Morse code. In one design of masthead lantern due to Captain Scott, and made by Messrs. Armstrongs, the lamps, which burn continuously, are inclosed in a lantern surrounded by two louvre screens, one fixed and the other movable. The movable screen is attached to the armature of an electromagnet, through which currents are sent when the signaling key is depressed. The

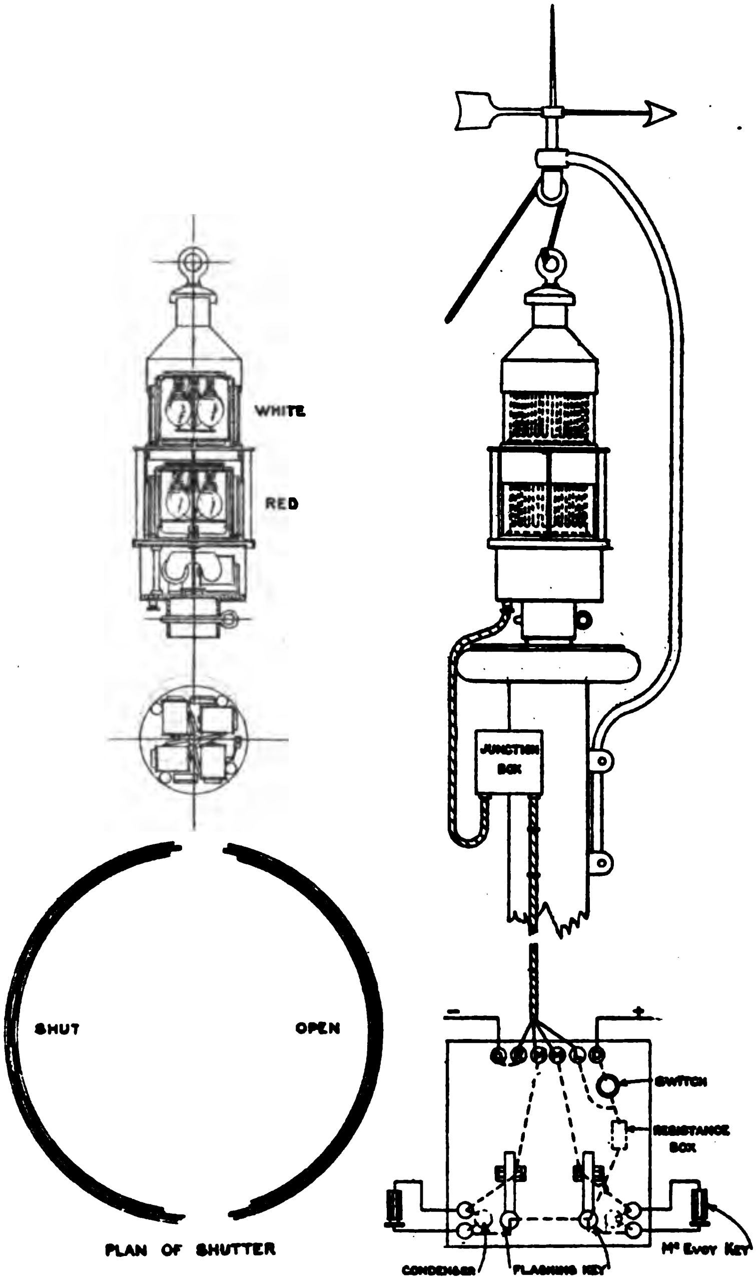


Fig. 16.—Double Mast-head Flashing Lantern, "Scott" System.

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lantern may be arranged so that openings in the louvres coincide and the lights are visible, when everything is at rest, the movement of the screen cutting off the light and thus representing the interval between the signals, or vice versa. A modification of the Scott lantern as used by the Japanese is shown in fig. 16. It consists essentially of two lanterns, one above the other, the lower one being inclosed in a ruby glass screen. There are independent signaling keys for the two lanterns, the

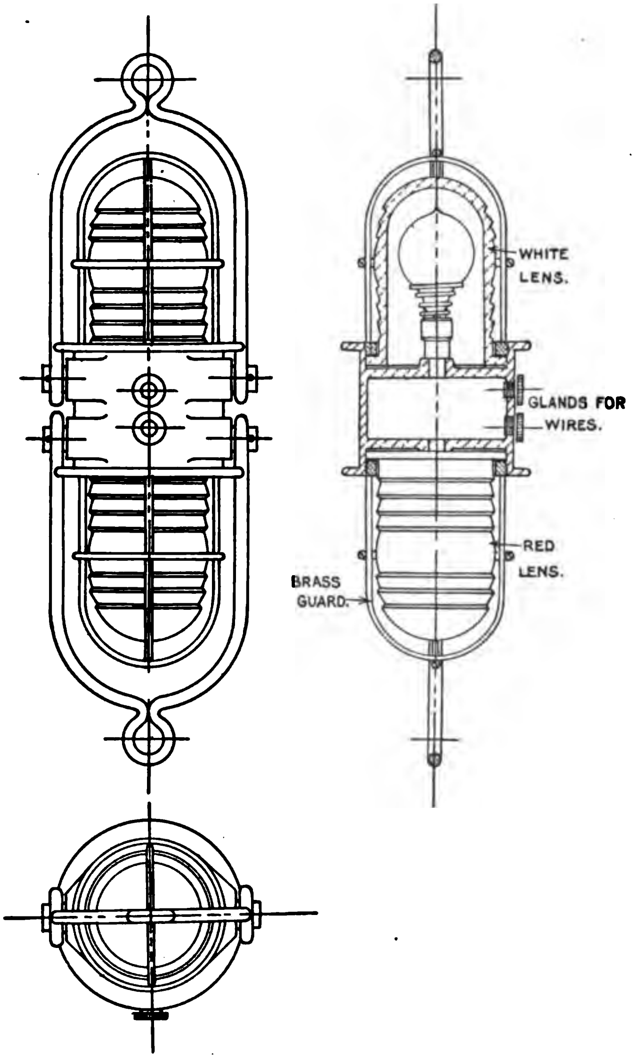

Fig. 15.—Ardois lantern.

contacts of which are shunted by a condenser and resistance to kill the sparking. In the figure the screen is shown to a larger scale for clearness.

The British masthead lantern is of different design, the lamp current itself being interrupted by the signaling key.

The United States Navy uses for fleet signaling four Ardois lanterns, the upper light in each being red and the lower white. These are suspended about 10 or 12 feet apart on a couple of wire jackstays from the aftermast. A special controlling switch is used, having sets of contacts corresponding one to each possible combination of four lights, the two lights in one lantern never being used together. Each combination denotes a letter of the alphabet or a figure. By moving the switch handle about the top dial of the switch and depressing at the proper contacts, words are spelt out.

SEARCHLIGHTS.

The searchlight installation is usually considered one of the most important sections of the ship's equipment, and use was found for searchlights five years before electricity was used for the general illumination of ships. The first projector was installed in 1876 in H. M. S. *Minotaur*. It had a vertical lamp burning square carbons, a parabolic mirror, dioptric and diverging lenses, and flashing screen. The lamp was hand fed and took alternating currents. In 1878 the Siemens holophote projector with automatic lamp was tried on H. M. S. *Triumph*; and many other forms of projectors and lamps were experimented with between that date and 1881, when the *Inflexible* was fitted with a Mangin projector, having a Mangin mirror instead of dioptric lens, and an inclined hand-feed lamp, current being furnished by a Gramme dynamo. The Mangin mirror is ground to spherical surfaces, the front and back having different radii of curvature. The parallelism of the beam is due to refraction through the thick glass between the front surface and the silver surface of the back. This remained standard in our navy until about 1893, when it gave place to the Parsons mirror, which is a thin parabolic mirror of high quality. The Mangin system is, however, in use by most foreign navies. The inclined hand-feed lamp is still the standard of the British navy; the carbons are tilted about 20 degrees from the vertical, and the light falling upon the mirror has its maximum intensity at or near the centre of the mirror. On the Continent and in the United States, automatic horizontal carbon lamps are coming into favor. The crater of the positive carbon is, of course, turned

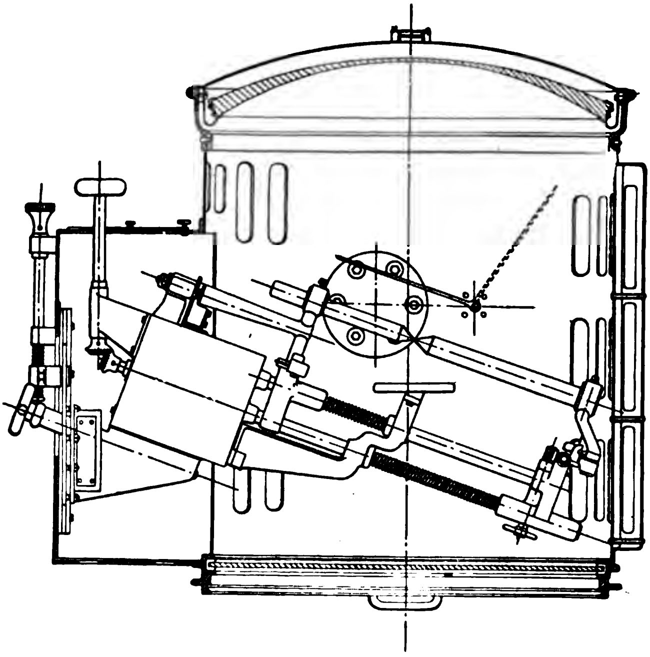

FIG. 18c.—Siemens' automatic projector.

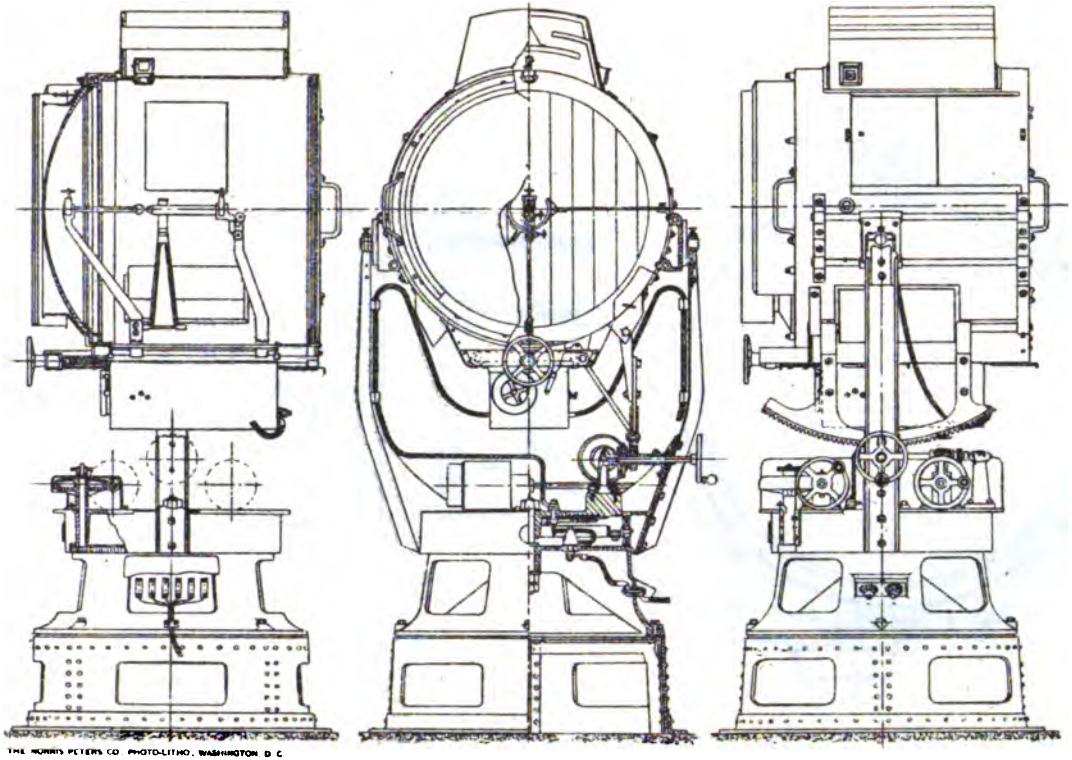

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FIG. 17.—Schuckert Automatic Projector.

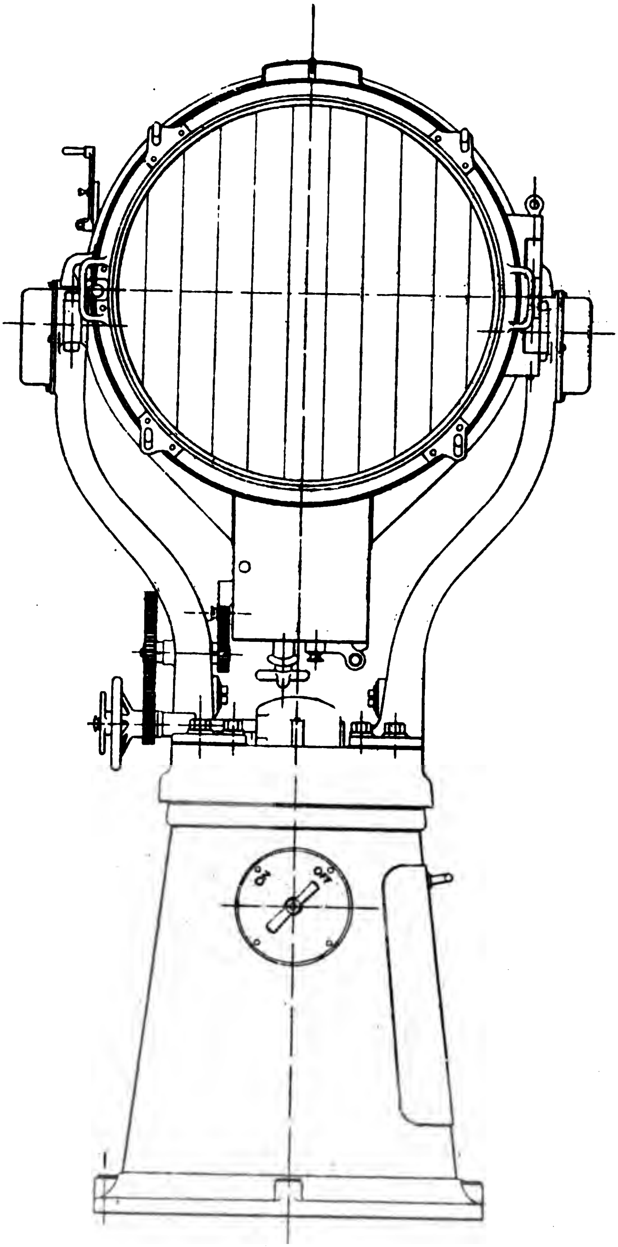

FIG. 18a.—Siemens Automatic Projector.

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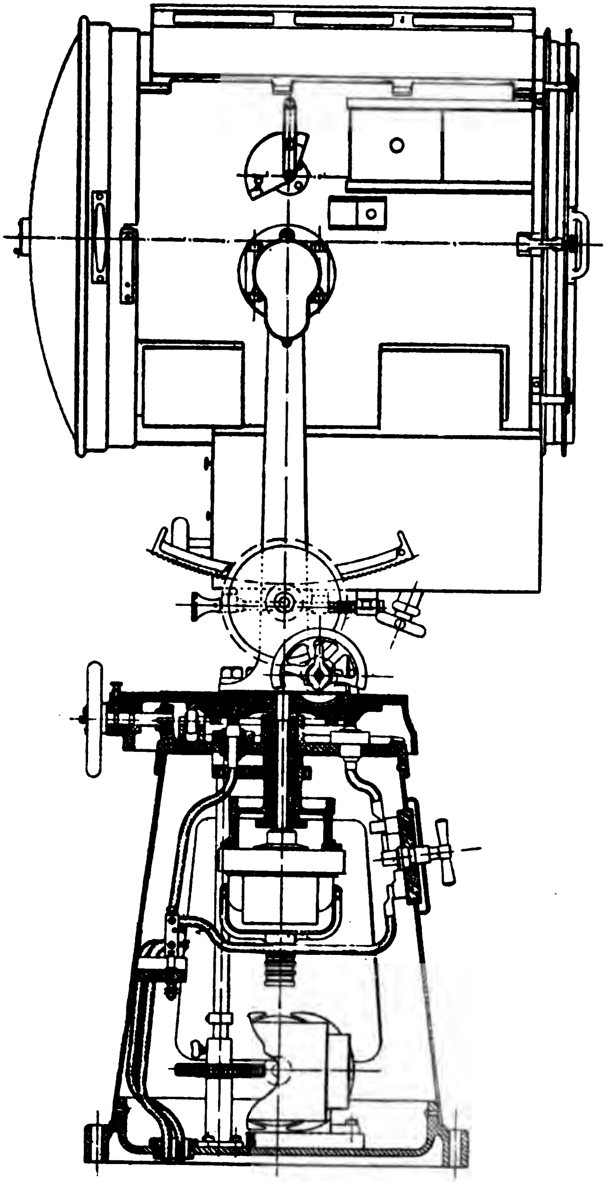

FIG. 18*b*.—Siemens Automatic Projector.

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toward the mirror, the arrangement in this case giving the maximum intensity of the light at the outer edges of the cylindrical beam. The British war office has also adopted the horizontal carbon lamp for its standard projectors. The ascending current of air is apt to displace the arc, which is specially inconvenient with horizontal carbon lamps. To get over this difficulty, the Schuckert projector, fig. 17, which is the standard in the Austrian navy, is fitted with a soft iron ring surrounding the carbon. This ring becoming magnetized when the current flows, produces a magnetic field along its axis in which the carbon lies, and so keeps the arc in the proper position.

It is now becoming common practice by foreign nations to operate searchlights from a distance. An observing officer can see the object illuminated very much better if he occupies some different position from that of the searchlight, so that he does not have to look along the beam. But, as he must have a means of directing the light, it is becoming common to provide projectors with electric motors, one to train and one to elevate the projector barrel, including lamp and mirror, and also to fit projectors with automatic lamps. This operation is specially advantageous as regards projectors fitted at the tops of the military masts, which can be conveniently operated from the bridges. Fig. 18 shows a Siemens electrically controlled projector of this kind. It is worked by a combination switch, consisting of two motor-starting switches mounted at right angles to one another, and worked by a single handle. The operation of directing the searchlight is done by moving the switch handle precisely as if one had hold of the back of the projector itself. The projector is instantly stopped upon a given object by bringing the handle to the "off" position, which short circuits the motors.

As fitted on the bridges of ships, projectors have two positions, a working position right out and a stowing position in board. At the stowing position they are secured by chains and turn-buckles to anchor plates in the deck; in the working position they are secured by a small eccentric motion, worked by a hand lever, which lifts the projector base slightly from its trolley wheels and jambs it on to the underside of a flange in the rail on which the projector runs.

Searchlights are used a good deal now for long-distance signalling, and very great distances indeed have been covered. The common way is to make use of a round disk suspended on a spindle running through the projector barrel, between the lamp and the mirror, and vibrating this disk by means of a small lever handle on the spindle. The arrangement is seen in fig. 18. In some recent foreign projectors a flashing screen, resembling somewhat a Venetian blind with the laths vertical, has been fitted in front of the front glass. The laths are linked together, and their movement from the position in which the full light is shown to that in which all the light is cut off, is controlled by a small lever handle mounted at the side.

VOICE PIPE AND BELL COMMUNICATION.

The problem of maintaining communication between the several compartments, cabins, and military positions in a war ship is not less important than the problem of maintaining general illumination, but it is far less successfully solved. As regards the communications between officers in their cabins and their subordinates and sentries, a simple system of bell signals with annunciators or "shutters" is all that is required; but communications between the navigating officers on the bridge and the engine rooms, and between combatant officers in the conning tower and the gun and torpedo stations, for example, may often be of a much more complex and special character than can be easily given by a simple code of bell signals. Beyond a certain point, means of verbal or telegraphic communication becomes necessary. Such communications in our navy are effected by speaking through copper voice pipes of 2-inch diameter, fitted with whistles or electric bells, pushes, and shutters, the latter serving merely to direct attention to the voice pipe. These electric-bell communications are very extensive in a modern ship, the number of points from which verbal messages can be sent or received being about 100 in the battleships of our *Majestic* class and about 140 in the *Canopus* class. A greater elaboration, however, than in any other ships afloat was effected in the Japanese battleships *Fuji* and *Yashima*, which were equipped with as many as 256 electrically connected speaking points, in addition to 44 cabin bell-push points.

The connections between stations are effected by four-core cable, the conductors being 1/16, separately insulated with rubber, and covered with differentcolored cotton coverings to facilitate making and tracing connections. The electrical connections of a pair of instruments are given in fig. 19. When, as is usual, several pipes and instruments occur at the same station, all the branching and jointing is done in terminal boxes. One bell is usually fitted common to the group, and one six-cell battery supplies several groups, the connections being made through suitable battery terminal boxes. The whole system is water-tight, and no jointing of wires is done outside boxes.

The problem of communication is, however, not solved by the present arrangements, the difficulty being that, when the electric bells have done their duty and the officers who wish to communicate are at the opposite ends of the voice tube, there is often so much extraneous noise that it is impossible for them to hear one another.

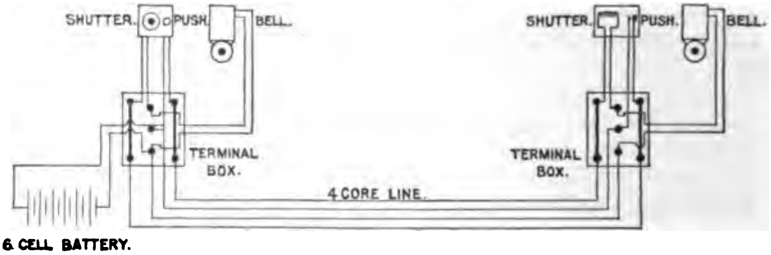

FIG. 19.—Voice-pipe Bell instruments, diagram of connections.

It has been usual in recent years carefully to insulate the tubes from the main structure of the ship, so that they shall not pick up sounds by conduction, and the device has been employed of leading the speaking tubes to about six exchange stations, where messages are received and transmitted, so that the length of tube spoken through between point and point is reduced to the smallest limits. The transmission of messages at exchange stations, however, introduces delay and sometimes error.

TELEPHONES.

The failure of voice tubes has given telephones their opportunity, the speaking qualities of the latter being practically independent of distance. Among the earliest to use telephones on war ships were Russia and America. One of the best forms of naval telephone, and one that is now being largely used, not merely by the British, but by many other navies, is Alfred Graham's. It is a loud-speaking instrument, the transmitter taking the current of four or six large agglomerate Leclanché cells and operating without an induction coil. The transmitter is of a granular type, inclosed in a water-tight case. It is turned half round every time the telephone is used by the switch which puts the line connections from "ringing" to "speaking." In spite of the large power employed there is no hissing. The receiver is contained in the same case. A considerable number of British battleships and cruisers are fitted with voice tubes and bells between the port-engine room and the bridges and conning towers, and with these telephones between the starboard engine room and the bridges and conning towers, the intention apparently being to gain extensive experience of the relative efficiency of voice tubes and telephones under identical conditions. Telephone connections in a typical case are shown in fig. 20. The most advanced instance of naval telephones yet fitted is to be found in H. M. new yacht *Victoria and Albert,* which has a large telephone installation. The trials are also being made of the applicability of these telephones to communications between casements.

It would appear, however, that during actual warfare, amid the noise and rattle of quick-firing guns, any instrument that depends upon the transmission of the human voice must fail. It is reported that in the battle of Santiago the Americans found their telephones useless. Unless a large number of men are to be told off as messengers to carry orders, what seems to be wanted is a system of printing telegraphs, the instruments being of a not too sensitive character, so that they could work without giving false signals due to vibration and shock, the general design of the instrument being somewhat after the fashion of that used by the Exchange Telegraph Company, printing in ordinary roman letters. Such an instrument would have a relatively slow speed of action, but its result would be more positive, inasmuch as the message could be read by a person without a telegraphic training, and if by chance a false letter were printed it would not necessarily prevent the word from being recognized. Probably its speed—twelve to twenty words a minute—is as quick, all things considered, as the average voice-pipe communication now. Of course, messages making inquiries or giving instructions in accordance with understood requirements could be transmitted by abbreviated signals.

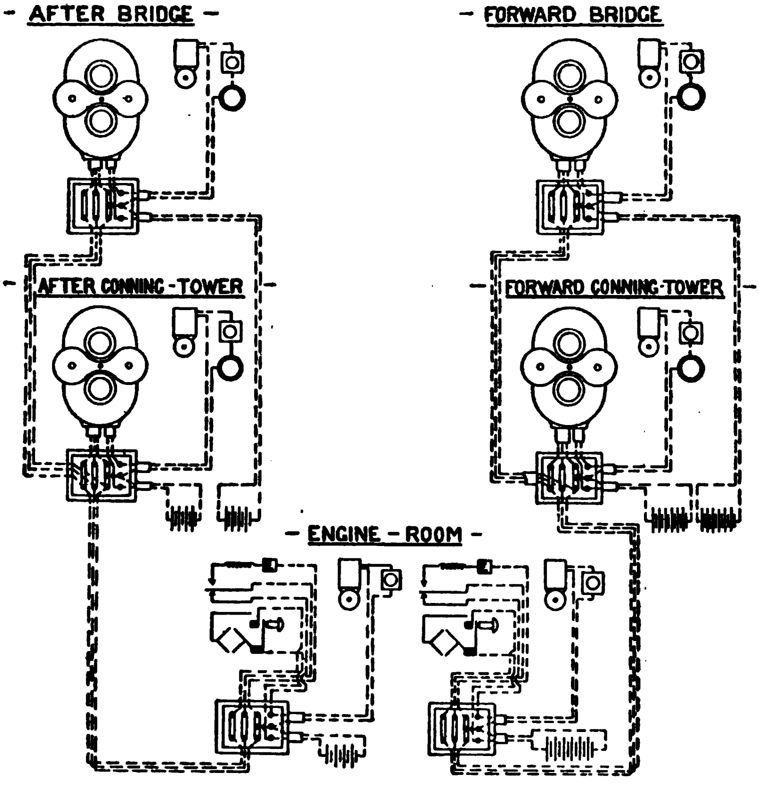

FIG. 20.—Graham's loud-speaking telephone, connections.

Before leaving the subject of communications, it may be mentioned that steps are being taken to introduce into the navy the "Sullivan" galvanometer for enabling ships at sea to speak with the land through ordinary submarine cables. There is some prospect also that war ships will make general use of the Marconi telegraphic apparatus for fleet and ship-to-shore communications. This apparatus proved very useful in the 1889 manœuvres, and equipments have since been supplied to some of the battleships of the Channel Squadron.

Among internal bell communications may also be mentioned alarms connected with thermometers for calling attention to the attainment of certain temperatures in magazines, coal bunkers, etc. The arrangement is obvious.

GUN AND TORPEDO WORK.

Electricity is an indispensable adjunct to the armament of a man-of-war, being invariably used for discharging torpedoes and for firing modern breech-loading guns of all sizes.

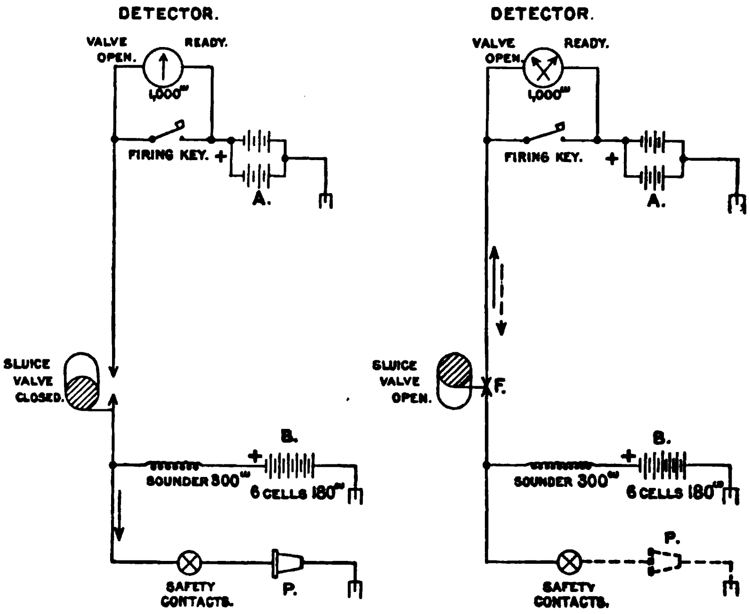

FIG. 21.—Torpedo-firing circuit.

While all other circuits in the ships are twin wired, gun and torpedo circuits are now universally single wired. The following are the arrangements used in connection with Elswick equipments:

TORPEDO-FIRING CIRCUITS.

Two batteries, one (A) of low and one (B) of high resistance, are connected with their positive poles toward one another as shown in fig. 21. The firing key and detecter are fitted in the conning tower, from which the discharge of the torpedo is controlled. The torpedo is placed in the tube, the sluice valve at the outer aperture of the tube being closed. The valve being closed, the firing circuit is open. The circuit is then "proved" by inserting a primer in the firing breech, when current flows from Battery B, causing the sounder in the torpedo room to start buzzing, thus indicating that all is right. The primer is then removed and the sluice valve opened, thus making contact at F and completing the circuit through E, B, F, A, E, the two batteries being in opposition. The detecter needle in the conning tower deflects to the left, indicating "valve open." The firing charge is inserted in the discharge chamber, the primer restored, and the breech locked. Current from Battery A through the high-resistance detecter then flows in unison with that from Battery B in the circuit E, A, F, P, E, reversing the deflection of the detecter and indicating "ready." The officer in the conning tower at the proper moment depresses his firing key, the two batteries send their full volume of current through the firing circuit in parallel, the fuse is ignited, and the torpedo discharged.

GUN-FIRING CIRCUITS.

These a few years ago involved a formidable amount of wiring, as the circuits from all the barbette and casemate guns were looped into the conning tower, where the firing keys were situated. The practice now is to fire all guns on short local circuits, the batteries, switches, keys, etc., being carried on the gun mountings. Fig. 22 shows the connections for a pair of Armstrong barbette guns. Following out the main (full line) circuit, it will be seen that if switches S_1, S_2 are closed and S_3 open, the left-hand pistol will fire the left gun and the right-hand pistol the right gun. If switch S_1 is open and S_2, S_3 closed, the left pistol fires the right gun; while if S_2 is open and S_1, S_3 closed, the right pistol fires the left gun. Finally, if all the switches are closed, both guns can be fired simultaneously from either side. An auxiliary circuit, shown in dotted lines, is fitted up as a stand-by to the main firing circuit. The latter is completed only when the gun is "right out;" the auxiliary circuit can fire with the gun in any position. The use of the sounders will be evident, as they buzz all the time the circuit is made. Whereas the firing pistols are usually fixed at the firing platform, the McEvoy keys, connected by flexible connections, enable the gunner to fire from any position.

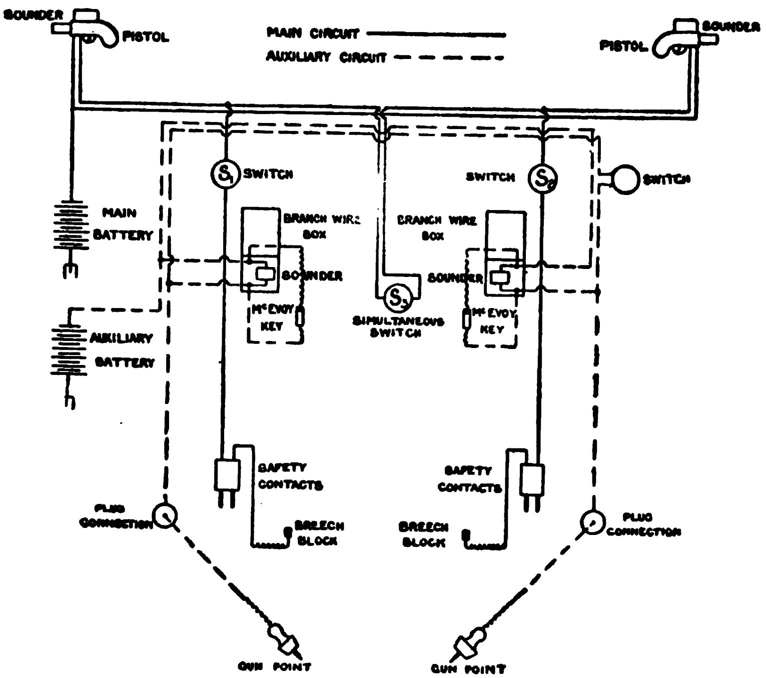

Fig. 22.—Gun-firing circuit.

* * * * * * *

NAVIGATION INSTRUMENTS.

(1) *Engine-room telegraphs and helm indicators.*

An electric system of engine-room reply telegraphs, worked out by Messrs. Richards & Evershed, was fitted in H. M. S. *Howe* and *Narcissus* in 1893, to H. M. S. *Royal Sovereign* in 1896, and since then in other British war vessels.

The indicating instruments have the appearance common to mechanical telegraphs, the dials being marked to show the usual direction orders "Stop," "Slow," "Half" and "Full," "Ahead" or "Astern." The revolution of the indicating hand is effected by the combined operation of two electro-magnets (see fig. 26) placed at right angles to one another and producing between them a cross magnetic field, within which lies a magnet with which the indicating needle is geared. The position of the needle depends solely on the relative strength of these two field components, and this depends on the ratio of the current in the two coils. This ratio is controlled by the "transmitter," which consists of a multiple contact switch, through which the ordinary 80-volt electric-light circuit is connected to a pair of ratio arms included in the same circuit as the coils of the indicator; the movement of the transmitter switches resistance out of one arm into the other, thus altering the relative value of the current strength in them, and controlling the movements of the indicator. An important detail is that the action does not depend on the absolute value of the currents in the indicator coils, but only upon their relative value, so that a constant voltage is unnecessary.

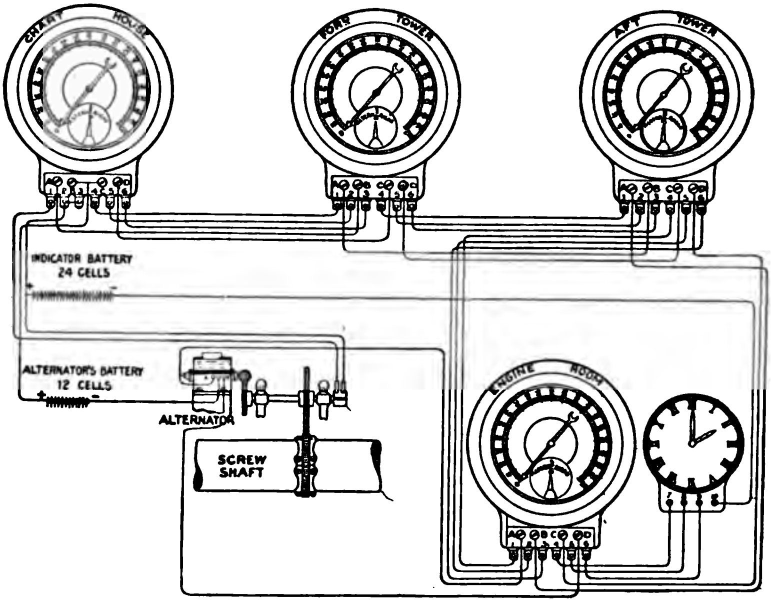

FIG. 28.—Molinari's engine revolution indicators.

A similar indicating instrument, graduated in degrees, is used for showing, at the several navigating stations, the angle made by the rudder, the transmitter switch in this case being automatically worked from the rudder crosshead (fig. 27). By means of switches these telegraphs can be arranged to signal from any of several working positions, bridges, and conning tower—to wit, transmitters send orders from any of these stations to a common receiving instrument in the steerage flat.

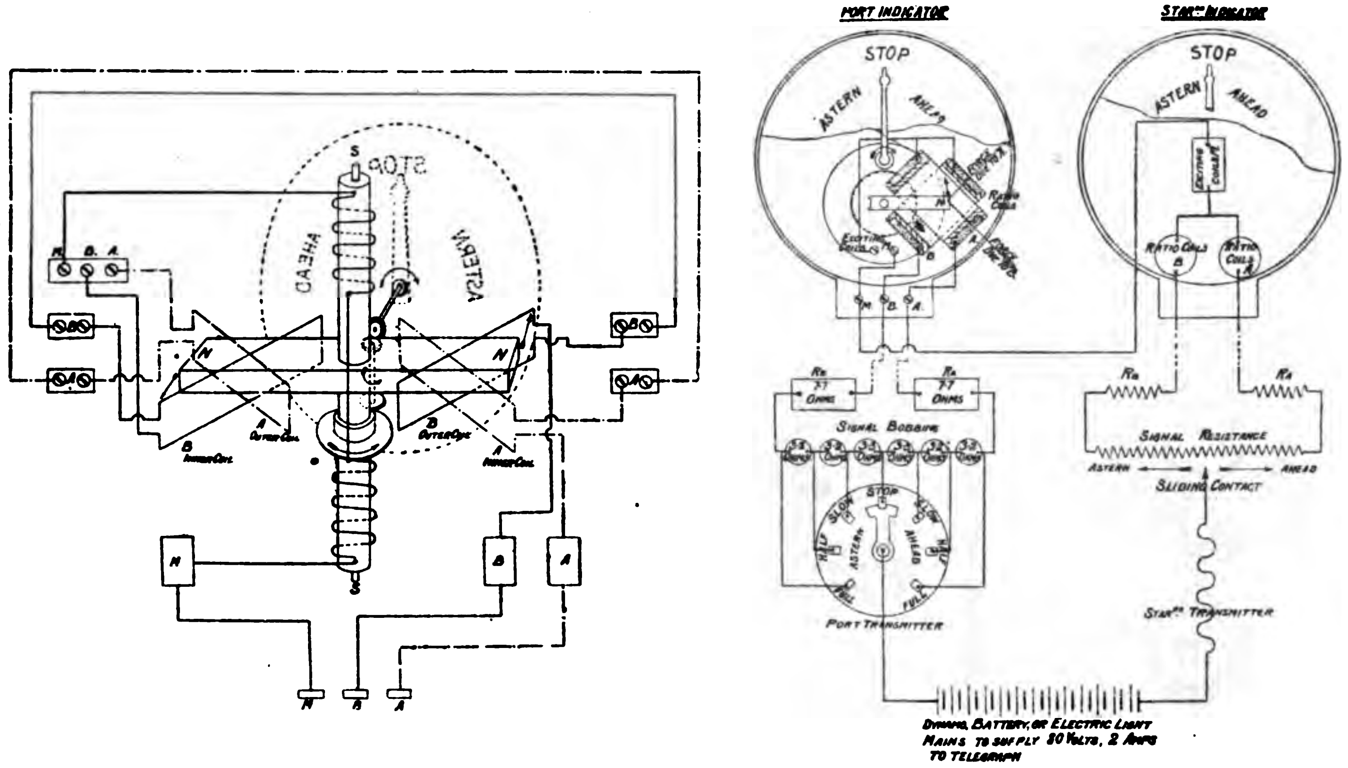

FIG. 26.—Richards and Evershed's Electric Engine-room Reply Telegraphs.

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(2) *Engine-room indicators.*

A system for showing simultaneously in the bridge positions, conning towers, and other navigating stations, the revolutions of each set of engines, and for indicating in each engine room the revolutions made not only by the set of engines in that room, but also by the set in the other room, is of great value. Such a system has been worked out by Signor P. Molinari, and has been adopted throughout the Italian navy and is also used on war ships of other countries. The indicating instruments (fig. 28) are direct reading in revolutions per minute. They are clockwork instruments, kept in synchronism by a standard clock. This standard clock has a commutator within it which sends current for twenty seconds into the coils of an electro-magnet in the indicating instruments, then breaks it for four seconds, reestablishes it for another twenty seconds, and so on. While this current is on, the electro-magnet holds a detent which allows an escapement motion to drive the indicating hand over the dial. Correcting currents, sent by a revolving contact maker driven by a friction wheel from the propeller shaft of the engine at the rate of three per revolution, are received in separate electro-magnet coils in the instrument, and while the main current, controlled by the standard clock, is disturbed for the four-second interval mentioned, the correcting currents drive the indicating needle forward or pull it backward according as the average rate of revolution of the engines has been less or greater than that shown at the moment on the dial of the instrument. A galvanometer telltale, for indicating "ahead" or "astern," is fixed in the bottom of the indicator case and receives current from what is called by the inventor an "alternator," driven from the shaft in one direction or the other according as the ship is going ahead or astern. When no current passes at all the needle takes the mid position and indicates "stop."

PART II.—MACHINERY AND POWER DISTRIBUTION.

The machinery of a modern ship of war consists of—

(*a*) *Main propelling machinery*, consisting of high-speed steam engines and high-pressure boilers. From the figures given by Sir William White, at the 1899 meeting of the British association at Dover, as to the output and efficiency of this class of machinery for a given weight, and from calculations made by Mr. Alexander Siemens as to the weight of accumulators required to perform the same work, there is no difficulty in concluding that electricity will have no place for many a long day in the propulsion of large ships.

(*b*) *Auxiliary machinery.*—This general title covers a variety of machines, whose functions fall into three principal classes.

(1) Those which cooperate with the main engines and boilers in the propulsion of the ship; e. g., boiler feed pumps, air and circulating pumps for condensers, fans for producing pressure in the stokeholds or furnace-blowing engines for working at "forced draft," steering engines, capstans for raising anchors, etc.

(2) Functions relating to the operation of the ship as a fighting machine; e. g., engines for moving turrets and for elevating and loading guns, hoists for raising ammunition, compressors for the supply of air under pressure to torpedoes, etc.

(3) Domestic functions; e. g., dynamos for lighting and fans for ventilating the ship, refrigerating plants for preserving food, pumping service for fire, bilge drainage, supplying fresh water and the like, hoisting machinery for lowering and picking up boats, etc.

In all, a first-class battleship carries nearly 100 sets of machinery, and a first-class cruiser 50 to 70 sets. Until a few years ago the whole of these auxiliaries were steam driven, with the exception of the gun-working machines, for which hydraulic power has long been preferred. By degrees electric driving has been applied to one and another, the most "advanced" examples being the United States battleship *Kearsarge*, just completed, which carries 55 motors and a generating plant of 350-kilowatt capacity. More has been written and said, both in Europe and America, within the last two or three years on this section of the subject than perhaps on any other, some persons roundly asserting that the time has come for driving all auxiliaries by electricity, while others are skeptical as to the desirability of employing electricity at all except for lighting and bells. Between these two extreme views opinions exist of every intermediate grade.

Electricity as a motive power is now so commonly used on land that the charge against naval administrations in general, and the British Admiralty in particular, that they do not sufficiently avail themselves of this new mode of transmitting energy is repeated with monotonous regularity by writers on the subject. It must, however, be remembered that it takes about three years to build and equip a large war ship; if any novelty has been introduced in the design of the ship, it is not unreasonable to allow a year for trial of the novelty at sea, whence it follows that the experience available to naval designers to-day is that of the methods of four years ago. Now, in electrical development four years is a long time, and thus it is evident that, judged by the standards of present-day land practice, naval designers would appear to be several years more backward than they really are.

The conditions under which auxiliary machinery works on board a war ship are of a very special kind, requiring motors of special design to meet them successfully. Thus, a glance at diagram No. 29 shows that auxiliary machines are located all over the ship. Boat hoists and ash hoists are located on the upper and boat decks, exposed to all conditions of sea and weather. Motors in barbettes and turrets, fans in ventilating trunks, and (sometimes) capstan engines are liable to be drenched with water by seas shipped, or at least to suffer from the effects of spray; the machines on the upper decks get covered with grit when coaling, while machines working in machinery compartments below decks have to endure high temperatures for prolonged periods. All, wherever situated, have to be able to withstand rough usage, and are liable to be left idle for long periods when the ship is out of commission. The mention of these difficulties suggests that, with very few exceptions, electric motors used on board ship should be of inclosed water-tight and dust-tight type, of extra strong mechanical construction to stand overloading, and arranged with long bearings and good automatic lubrication, so as to run for long periods with no attention at all; they should also be designed to work sparklessly with constant lead for all loads, so that the brushes are fixed; and, moreover, the brush gear must be so designed that the brushes do not jump off the commutator if the machine is exposed to external vibration; the motors should run for normal periods with moderate temperate rise (the rise permissible depends on what is called the "normal period" of running, and will be different in such cases, for example, as electric ventilating fans, which ought to be able to run for two or three weeks on end, and capstan motors or boat-hoist motors, which in normal circumstances would work less than an hour at a time). The switch gear should be of massive construction, and should be an engineering apparatus, as substantial as a stop valve or a starting lever.

It can not be said that all these requirements could have been met by the general run of electric motors produced four or five years ago, but they can all be met to-day. Cases, unfortunately, have occurred in which motors fulfilling none of the above conditions have been put on board ship. The cheap stock motor, suitable only for dry situations on land with good foundations, and requiring careful attention, has been installed and sent to sea. When, as is inevitable, such motors fail, the report sent in is less likely to be to the effect that "this particular motor is unsuitable" as that "electricity is not adapted to this class of work."

The modern traction type of motor best meets, on the whole, the requirements laid down as necessary for ship work, and the conditions under which it actually

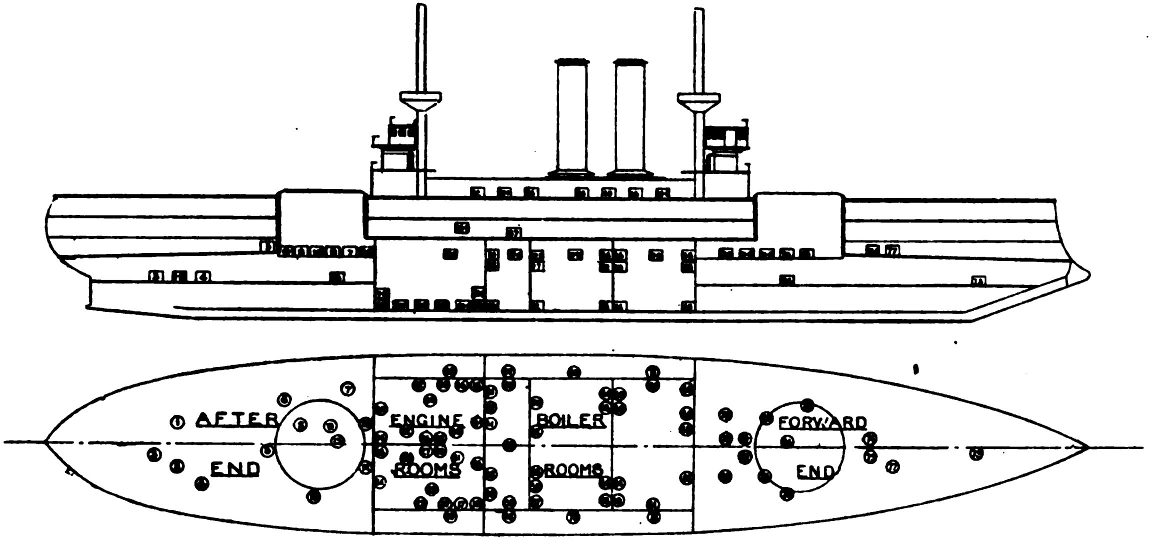

FIG. 29.—Location of Auxiliary Machinery on a Typical Battleship.

1-2.	Steering Engines ..	2 sets
3.	After Capstan.	
4-7.	Ventilating Fans ..	4 sets
8-9.	Air Compressors ..	2 sets
10.	Main Hydraulic Engine.	
11-12.	Turret Turning Engines	2 sets
13.	Turret Auxiliaries— Shot Hoists, Rammers, etc.	
14-15.	Steam Dynamos ..	2 sets
16-19.	Main Circulating Pumps	4 sets
20-21.	Auxiliary " "	2 sets
22-25.	Air (*i.e.* Hotwell) Pumps	4 sets
26-29.	Fire and Bilge Pumps	4 sets
30-31.	Starting Engines ..	2 sets
32-33.	Turning Engines ..	2 sets
34-35.	Distiller Pumps ..	2 sets
36-37.	Ventilating Fans ..	2 sets
38-39	Ammunition Hoists ..	2 sets
40-45.	Boiler Feed Pumps ..	6 sets
46-50.	Furnace Air-Blowing Engines	5 sets
51-56.	Ventilating Fans ..	6 sets
57.	Steam Dynamo.	
58-59.	Boat Hoists	2 sets
60-61.	Coal "	2 sets
62-66.	Ash "	5 sets
67-72.	Ammunition Hoists ..	6 sets
73.	Capstan Engine.	
74-75.	Refrigerators	2 sets
76.	Workshop Engine	
77-80.	Ventilating Fans ..	4 sets
81-82.	Air Compressors ..	2 sets
83.	Main Hydraulic Engine.	
84-85.	Turret Turning Engines	2 sets
86.	Turret Auxiliaries— Shot Hoists, Rammers, etc.	

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works on land are as bad, if not worse; yet the accumulating experience of the world that such motors will endure the very roughest usage, makes it unnecessary to argue further that inclosed motors can be built, of moderate weight and cost in relation to output, that will leave nothing to be desired on the ground of reliability.

Reliability being the first consideration, the next in importance is simplicity in operation, combined with ease of inspection and repair. An electromotor is a simpler machine to operate than a steam or hydraulic engine. It has fewer working parts requiring attention. Indeed, if only attention is given to supplying the bearings with oil and to cleaning the commutators periodically, there is nothing else for an attendant to do. Also a motor is cleaner in operation; it is not necessary to drain out a pipe full of water before it will start, and not only is the mess due to the absence of drainage water saved, but there is the advantage that the motor can be started instantly.

Cables for motors may, in like manner, be held to be a simpler means of transmission than steam or hydraulic pipes; they are more easily led about, weigh less, and take up less room than pipes capable of conveying an equivalent power, and they interfere less with the structure and disposition of space in the ship. It has been objected against them that faults in cables are not so easily found as in the case of steam pipes, but if the cables are originally water-tight and are led about the ship from point-to-point junction or fuse boxes, it is not difficult to isolate the sections one at a time and locate the fault rapidly. If a fault exists, when it is found it can be repaired much more expeditiously than a leaky joint or other fault in pipes can be, especially steam pipes, which have to be allowed a long time to get cool before they can be handled. Further, if it is not convenient to repair a cable fault immediately, a temporary length of cable, not necessarily of the same size, can be run in and the faulty section disconnected; this can not be done with pipe systems of distribution.

American writers point out two other disadvantages attending the use of steam-pipe systems of distribution—(*a*) that the steam pipes heat the living spaces to an uncomfortable extent; (*b*) that pipes exposed to the effects of shot and shell are likely to be injured in action, and to lead to the demoralization of the guns' crews. Neither of these considerations apply to modern British ships. Steam pipes do not pass through living quarters. Pipes to the steering and capstan engines pass through certain storerooms below the protective deck, but these are so chosen that the heat is unobjectionable. As regards the pipes to the deck hoists, which are exposed, they are usually led up the stokehold fidleys amidships, and are provided with valves below by which they can be shut off from the steam main in time of action.

EFFICIENCY.

The mechanical efficiency of an electric motor is, as a rule, a few per cent higher than that of a steam engine of corresponding power. The efficiency of the system as a whole involves the consideration of the generating and distributing arrangements, and here electricity has a marked advantage over either steam, compressed air, or hydraulics, the power taken being strictly proportional to load and the overhead efficiency from I. H. P. of generators to B. H. P. on motor shafts averaging about 65 per cent at full load.

Efficiency, however, can not be considered alone. The naval architect wants the relative advantages of competing systems expressed in terms of weight and space. In a given ship of war the correct adjustment of weights and dimensions is correlated with the maximum offensive and defensive qualities involved in armor and armament, speed and coal endurance. Hence, unscientific as it may appear in itself, an electric power distribution system of high mechanical efficiency may be a positive disadvantage to a war ship if the weights involved conduce to an unfavorable design in the offensive and defensive qualities of the ship. Whether the change from steam to electric driving of auxiliaries involves the sacrifice of greater weight than is compensated for by the advantages gained is precisely the question on which authorities differ—the differences being chiefly due to the use of general terms for the sake of the argument instead of precise calculation.

The main sources of loss in operating steam-driven auxiliaries are three: (*a*) The use of too great a range of temperature and pressure in the cylinders; (*b*) leakages past pistons and valves due to wear; (*c*) steam-pipe condensation.

* * * * * * *

The questions next arising are: To what purposes is it practicable, having regard to all considerations, to adapt electric driving; what would be the changes in weight, space, etc., involved, and what should be the arrangement of the installation for supplying the power?

There is a broad difference at once to be recognized between machines directly cooperating with the main propelling machinery and those performing other duties. On the whole, present engineering opinion is, from considerations of reliability, decidedly in favor of continued steam driving for boiler feed pumps, circulating and hot well pumps, fire and bilge and distiller pumps. It happens that these pumps are the worst steam eaters in the ship. In the *Minneapolis*, for example, the consumption ranged from 75.74 pounds in a circulating pump doing 4.1 I. H. P., one cylinder alone taking steam, to 318.68 pounds for a small pump developing 0.78 H. P., which was used for flushing purposes, the average for the twelve pump tests included in Mr. White's tables being 161.61 pounds per I. H. P. hour. Experience with electric auxiliaries in other situations may eventually lead to the use of electricity for these services; but this contingency may be left out of account for the present.

Starting and turning engines may be regarded as parts of the main engines themselves, and of course will be driven by the same power.

The only auxiliary services within the engine and boiler rooms for which the use of electricity may be considered at present are ventilation and furnace blowing.

FANS FOR ENGINE AND BOILER ROOM VENTILATION.

In the *Canopus* class of battleships each engine room is ventilated by a 7 foot 6 inch fan driven by a direct-acting steam engine, while the boiler rooms are supplied with air from four 8-foot fans at 240 revolutions, and two 6-foot fans at 320 revolutions per minute. These represent in the aggregate about 150 I. H. P., with a weight of between 3 and 4 tons. The *Duncans* will carry two engine-room fans, each 6 feet 6 inches in diameter, with two 8 foot 3 inch and eight 6 foot 6 inch fans in boiler rooms, the speed being about 300 revolutions. Fan driving, being a purely rotary movement, is a duty which electric motors have shown themselves excellently able to perform. They can run at at least twice the speed of reciprocating engines for the same power without noise or vibration, and can give the required deliveries with smaller fans, with higher efficiencies in both motors and fans, and therefore with less total power. It would probably be reasonable to take the total power of motors to perform the engine and boiler room ventilation of the most powerful ships at about 80 B. H. P. on the fan shaft, say 100 E. H. P. input, which could be provided in inclosed type motors built for continuous work at 750 revolutions per minute for about 3 tons, or, allowing for the weight of the fans, an increase of not more than 1 ton on the above total weight.

FURNACE AIR-BLOWING ENGINES.

These are high-pressure air pumps adapted for delivering air at 15 to 30 pounds pressure above the fires and into the combustion chambers of the boilers. A set of five such engines in the *Shikishima* weigh 5 tons 2 cwt., and develop an aggregate of 220 I. H. P. Pumping services of this kind are very efficiently performed electrically, but the substitution of geared motors for engines would result in this case in an increase of the total weight probably to the extent of about 3 tons for 200 E. H. P. Furnace air engines are generally placed in the boiler rooms, but if electrical they could more conveniently be placed outside or above the boiler rooms, air pipes only being led into the firing compartments.

Considering next the auxiliary machinery outside the engine and boiler rooms we find these include steering engines, capstan engines, boat, coal, and ash hoists, ventilating fans, air compressors, refrigerators, workshop engine, turret-working machinery, and ammunition hoists.

STEERING ENGINES.

It is convenient to consider these machines in this section, as they are usually placed in the after steerage flat adjacent to the tiller compartment. In some of the latest British ships they are placed in the engine rooms and connected by long lines of shafting to the tiller mechanism. This arrangement saves carrying steam pipes aft but seems to have nothing else to recommend it.

Next to the main engines these are the most important in the ship, and before every question of weight or efficiency the most reliable machine must be used here. Electric steering engines have, the author understands, been made, and there seems no reason, as far as the motors are concerned, why equally positive results should not be obtained with these and with steam engines. The controlling of their motion is the principal difficulty. The motors would be everlastingly starting, stopping, reversing, and altering speed; or, if the motors ran continuously, then such movements would be always being made by the gears and clutches. And whereas the steering engine is deep down in the ship the control has to be operated from distant stations, of which there are usually five, interconnected, the forward bridge and conning tower being the most important and the most generally used. Simple rheostatic control from a distance is not good enough; to secure the necessary sensitiveness a large number of switch contacts and connections would be necessary, and an extensive system of cables interconnecting all the steering stations is inadmissible. A maker of steering engines once told the author he had invented an electric steering engine which he was sure met every requirement, but it required 79 wires. The reply was, of course, that 79 wires would kill any such project. Recourse must be had either to a pilot motor, worked by a small switch and two or three wires, operating in its turn the controller of the steering motor proper (indeed, it would probably be possible to employ the hydraulic telemotor, now so largely used, for working electric controlling switches alongside the steering motors, in similar fashion to that in which it reverses the valves of the steam steering engine), or to the interaction of two machines, as in the Ward Leonard system of controlling turrets. If the difficulty of control be satisfactorily overcome, the gain in efficiency of electric steering mechanism ought to be very substantial, owing to its long periods of work. From its irregularity of working it is impossible to define the average H. P. of a steering engine. The motor to replace it must be a substantial affair, heavily geared, the torque required on the rudderpost of a big battleship being as much as 500 ton-feet. To move the rudder from hard-a-port to hard-a-starboard in thirty seconds, which is the usual requirement, a steering engine will make about 300 revolutions, and working at this maximum rate the I. H. P. will lie between 300 and 400, and the useful work done on the rudderpost will be at the rate of about 75 H. P. net, an overall efficiency of 20 to 25 per cent. Each steering engine with its gear weighs 5½ to 6 tons; two sets are carried. If each steering engine were replaced by one motor capable of exerting the same starting torque, the full load rating of each motor on continuous work might be taken at 150 H. P., though the starting current allowed would correspond to twice this power. With electric driving, an improvement in efficiency might be expected. The extra weight involved, using open-type machines, would be about 2 tons per set.

The principal capstan is, of course, the forward one, which has to operate the heaviest anchors. Besides other stipulations, its engines (usually duplex) are required by our admiralty to lift a weight of 35 tons at the rate of 25 feet per minute = 60 actual H.P. The maximum I.H.P. may be taken at 200, and the weight of the complete capstan with engines and gears is about 47 tons. If electric motors were substituted for the steam engines with the same gears this weight would be increased by about 2 tons; but with better designed worm gears the work could be done electrically on the same total weight. The after capstan performs similar but lighter work, lifting 15 tons at 25 feet per minute = 25 actual H.P., say 75 I.H.P.

In our latest ships, while the forward capstan is still steam-operated, the after capstan is specified to be driven by two reversible water-tight motors, performing the above-specified work at speeds not exceeding 750 revolutions per minute, and so designed that the rise in temperature after one hour's run at full load does not exceed 80° F. This change involves an increase of total weight in capstan, motors, and gear of from 1 to 2 tons.

In lieu of two motors the admiralty have accepted for the *Duncans* and other ships an electric capstan driven by one 50 H.P. motor at 350 revolutions per minute, the weight of the complete capstan, motor, and gear being approximately the same as that of the steam after capstan of H. M. S. *Albion*.

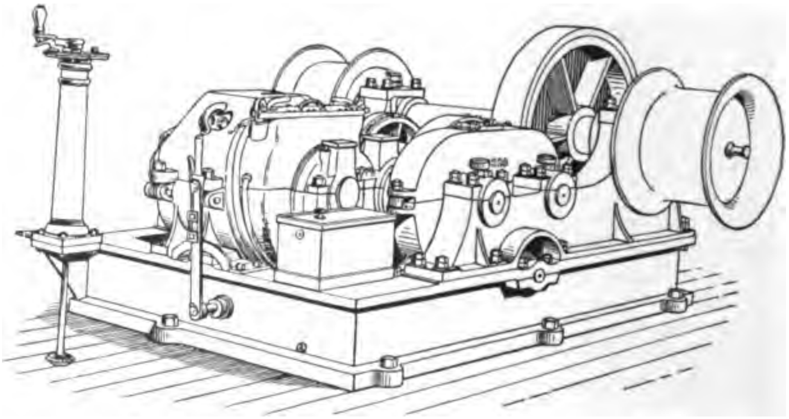

FIG. 31.—Electric deck-winch, U. S. S. *Kearsage* and *Kentucky* (General Electric Co.).

Fig. 30 shows the general arrangement of the electric capstan of H. M. S. *Irresistible*, by Messrs. Clarke, Chapman & Co.

It will require a somewhat protracted experience to determine whether, on the whole, the use of electric motors for capstans proves advantageous. To be quite safe, motors should be used with a large margin of power, notwithstanding the increase of weight involved, for the stresses involved in such work are apt to rise with great suddenness to many times their average value, and capstan chains have a habit of jamming in the stops. If steam driven, the engine will pull up, and is able to stand under the load; a motor can not do this, yet it can neither be allowed to burn up nor to relinquish its work by cutting itself permanently out of circuit. Special devices are necessary to meet such a condition. Mr. Siemens dealt somewhat fully with this matter at Dover; so it is unnecessary to dwell further upon it here.

Neither in this case nor in that of the steering engines do there appear to be difficulties incapable of satisfactory solution electrically, and in these cases the longest steam pipes in the ship are concerned.

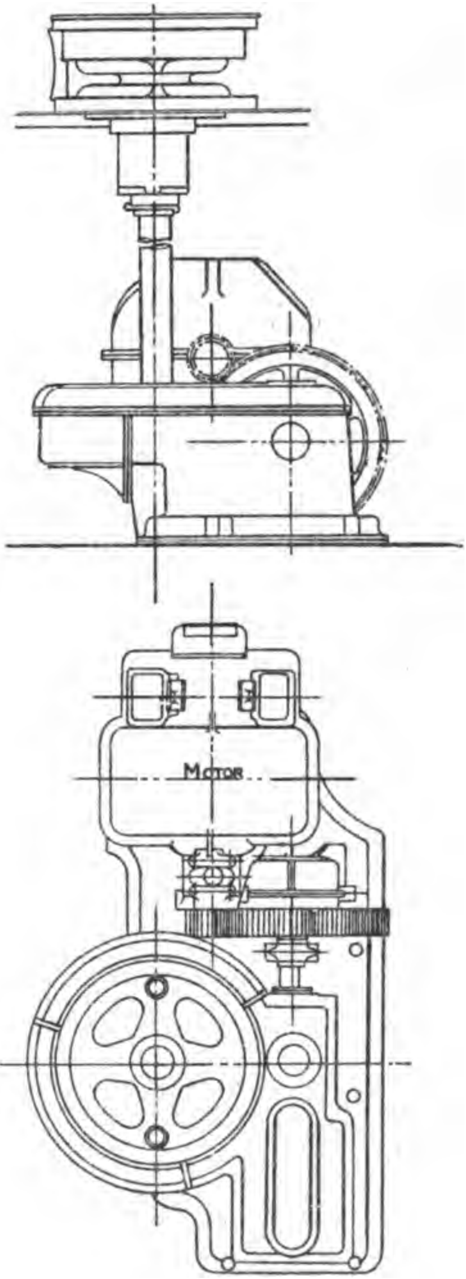

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FIG. 30 ELECTRIC CAPSTAN, H. M. S. "IRRESISTIBLE."
(CLARKE, CHAPMAN & CO)

BOAT-HOISTING ENGINES.

A British battleship carries two sets, one on either side, of such power that each set can lift, by means of tackle, a boat weighing 18 tons at not less than 20 feet per minute. This is a favorable case for electric driving, and in the latest British ships electric motors are specified for the work. The actual net H. P. for the lift is approximately 24, and as the motors have to drive through a worm gear and a wire-rope tackle, the maximum input may be taken at about 50 E. H. P. The motors are specified to run at not more than 750 revolutions per minute, to be water-tight, and to be fitted with reversing switches and automatic brakes. The rating of the motors is determined by the temperature limit of 80° F. rise after one hour's run at full load, which enables the weight of the total equipment to be about the same as that of the steam hoist.

An electric compound deck-winch, as fitted in the U. S. battleships *Kearsarge* and *Kentucky*, is illustrated in fig. 31.

COAL HOISTS.

These machines (of which two sets are carried) are of the same class as the boat hoists, but work at a quicker rate. The latest British specifications define their work to be the lifting of 1 ton at 250 feet per minute, but on test they have to lift 1½ tons at this rate. On the test load they have to exert 25 actual H. P., and though the efficiency may be a little higher in this case than in that of the boat hoists the total input will be 40 to 50 E. H. P. The motors therefore may well be of the same size; they are governed by the same specification as to temperature limit, control, etc. The weight of the motors and gears will probably be a few hundredweights more than that of corresponding steam hoists.

ASH HOISTS.

One of these is usually fitted to each boiler room; the *Albion* carries five. Their work is not definitely specified, but may be described as lifting with wire-rope tackle a bucket of ash, weighing when full about 1½ cwt., at from 200 to 250 feet per minute = 1½ actual H. P., the maximum I. H. P. of the steam engines being about 5 on a weight of 14 cwt. Being placed on the boat deck, machines of this class may well be electric, and as the motors will run at higher speed than steam engines no increase of weight need be involved.

VENTILATING FANS.

are employed for ventilating all compartments below the protective deck and some of the compartments above that deck, such as mess and living spaces. The general practice up to 1898 was to provide six 5 ft. 6 in. double-breasted steam fans on lower deck, three at each end of ship, driven at a maximum speed of about 400 revolutions per minute, and connected together to main ventilating trunks, besides an auxiliary system of ventilation with one 4 ft. 6 in. fan at each end of the ship. The electric driving of ventilating fans is now common in most navies. Fig. 32 shows a Sturtevant fan with open-type motor as used in the United States Navy.

In a few recent ships electric fans of from 3 to 4 feet diameter have been fitted, taking about 7 H. P. at 600 to 700 revolutions per minute, the same number (8) being employed and connected to the same system of trunks as designed for steam fans. Figs. 33, 34, and 35 show a 3 ft. 9 in. electric fan of this sort, designed by the author and fitted in the I. J. B. *Shikishima*. These fans have been adjusted to deliver 7,500 cubic feet of air per minute, each at 2 inches pressure at 480 revolutions per minute, at which output they consume 5 E. H. P. apiece, but their speed and output can be increased if desired.

Experience has shown that the matter of ventilation has been somewhat overdone in recent years, such powerful fans being seldom worked at their full speeds and powers. Accordingly, in the latest British ships, i. e., all designed since 1898, a larger number of smaller fans with shorter and simpler trunks are employed. The *Duncans*, for example, will each carry 14 fans not exceeding 24 inches in diameter, with motors of about 2 B. H. P., delivering 1,500 cubic feet of air per minute at 2 inches pressure.

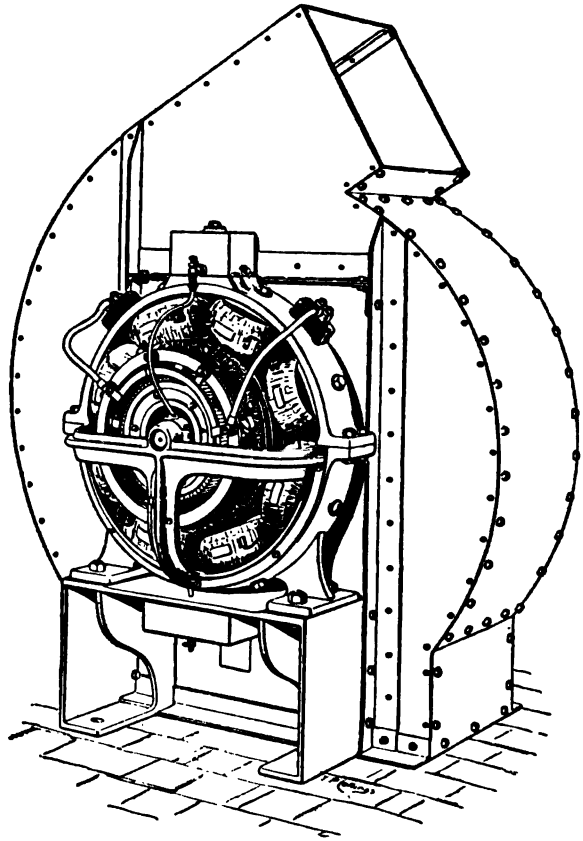


FIG. 32.—Sturtevant blower, with General Electric Company's motor.

AIR COMPRESSORS FOR TORPEDO WORK.

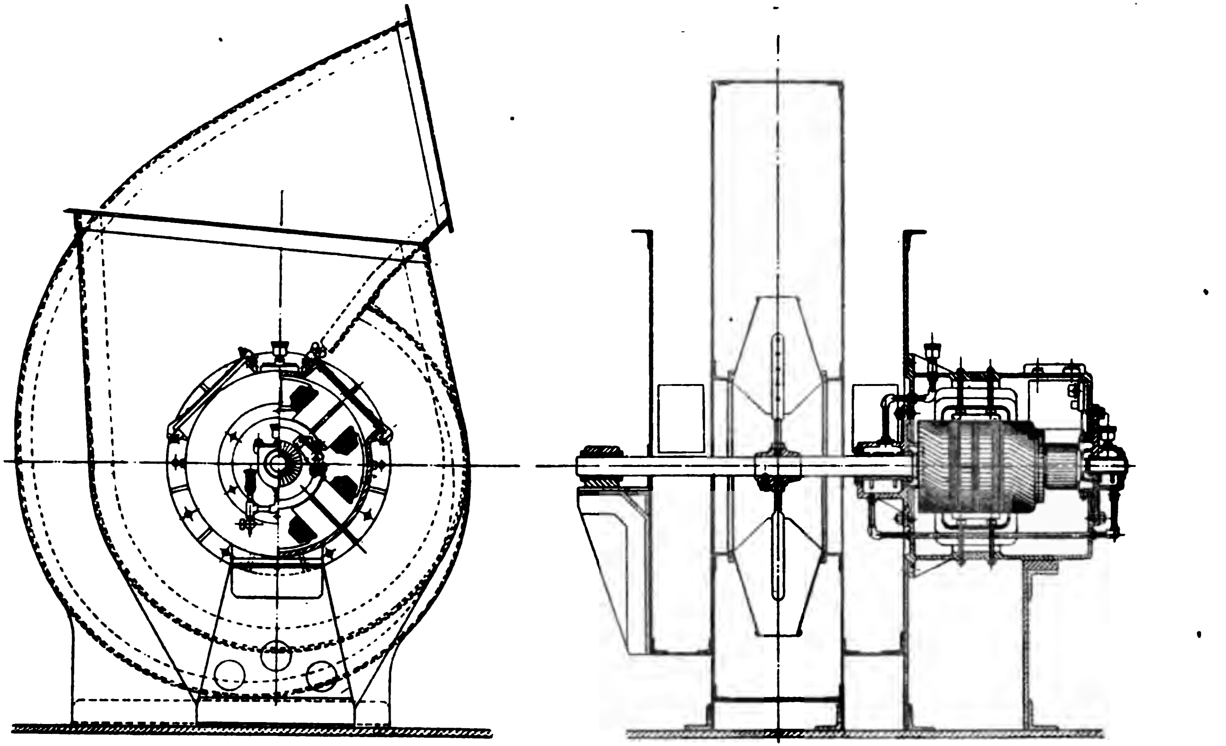
A modern first-class battleship carries usually four sets, each capable of delivering 30 feet of air compressed to 1,700 lbs. per square inch in 70 minutes. This involves an average B. H. P. of about 50 to 60 per set of pumps on a little less than 3 tons weight. Electric compressors would involve quite a different design, but would result in much quieter and smoother working. The weight would remain approximately the same.

WORKSHOP ENGINE.

This is a small engine of about 5 H. P., driving one or two short lines of shafting actuating half a dozen machine tools in the engineers' workshop. It is an obvious case in which electric driving is handier than anything else.

GUN-WORKING MECHANISM.

A modern battleship, mounting two pairs of large guns en barbette, carries quite a nest of machinery for working the guns. There are engines for training the turret,



FIGS. 33 AND 34.—Ventilating Fan and Watertight Motor, H.I.J.M.S. "Shikishima" (Thames Iron Works).

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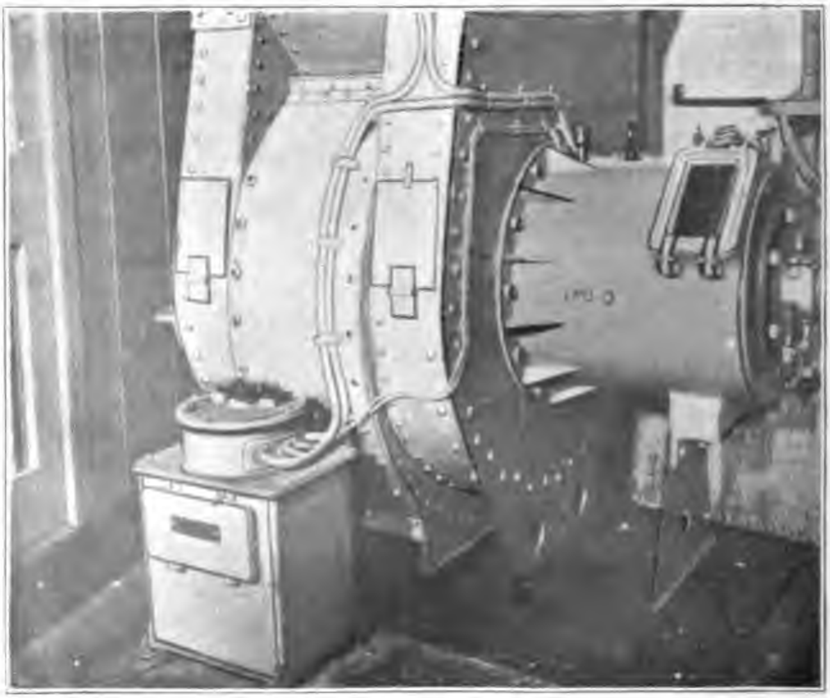

Fig 35.—GENERAL VIEW OF MOTOR FAN AND CONTROLLER, H. I. J. M. S. SHIKISHIMA.

independent engines for each gun for elevating and depressing and for running in and out, rammers for loading, hoists for bringing up powder and shell from the magazines below, besides lifting and traversing gear for transporting shot and shell from the bins in the shell rooms to the handing-up cage. Some of the machines are duplicated and some triplicated, and there are always in conjunction hand gears for continuing the work if the mechanism fails.[1] In a ship carrying hydraulic mountings the power is supplied by a steam-hydraulic pumping engine of about 250 I. H. P., situated below and adjacent to the barbette. A pump in the barbette itself is used for circulating the water in the pipes under pressure for use over and over again if the pumping engine below is out of use. The hydraulic supply to each barbette is interconnected with that to the other, pipes running fore and aft along the ammunition passages below the water line.

Hydraulic power has been almost universally used in our navy for the last twenty years. Steam is used a good deal in the United States Navy, possibly because their ships have to operate in latitudes where extremes of temperature are common, and where, therefore, hydraulic appliances are liable to be disabled by freezing. But steam has great disdvantages for the purpose. The working being intermittent, there is great difficulty in starting owing to condensation, and there is further the serious liability to injury to the steam pipes in action, with possibly disastrous results to the gunners.

Electricity has come to the front in recent years as a rival to the older hydraulic system. By the English Admiralty it has scarcely been used at all. In the *Majestic* class of battleships electric motors have been put in as an auxiliary for training the turrets, but these are small-powered machines intended only as a help to the hand gear, the primary installation being hydraulic. A beginning was also made in cruisers by applying electro-motors to the 9.2-inch guns of H. M. S. *Terrible*. In the Japanese battleships fitted with Elswick armament an auxiliary electric training gear is carried, but the motor is about 15 H. P. capacity, and is able to train the turret at the rate of about 2° per second. The pump referred to above is also electrically driven.

In the United States Navy electricity has been more largely used, and, as compared with steam, earned in the late war good reports in respect of quickness of action and precision of control. The *Brooklyn* had two turrets trained by steam and two by electricity, which favored a direct comparison. The electric turrets are said to have been started and stopped thirty-seven times in a minute and to have been capable of very small motions at a time. The success of the electric motors in the first ships led to their extended use in later ships, and in the *Kearsarge* and *Kentucky* not merely are the turrets trained, but the guns are elevated and the ammunition hoists and rammers worked by electric motors. At the present time there seems to be a revulsion of feeling against electric installations. Lieutenant Norton (speaking apparently on behalf of the American constructors) said[2] that in the new large triple-screw ships being designed for the United States Navy it has been decided not to use electrical power in the turrets except for the hoist, for the reason that "you can tell what is the matter with a steam or hydraulic engine instantly; but you may chase for hours to find a broken circuit, and by that time the action is over and you are out of the deal." To understand this remark the difference in the character of American and English installations must be borne in mind.

For controlling turrets the Americans use an ingenious method devised by Mr. Ward Leonard, which may be fittingly mentioned here. In the turret is a motor

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[1] Illustrated descriptions of the turrets and gun mountings of several British and foreign ships are given in a paper entitled "The rise and progress of rifled naval artillery," by Sir Andrew Noble K. C. B., F. R. S. (*Proc. Inst. Naval Architects, 1899.*)

[2] Discussion on Admiral Melville's paper, "The logical arrangement of the motive power of warships," Inst. N. A., March, 1899.

(or a pair of motors in parallel) separately excited at constant voltage. Its armature is directly connected with that of a generator in the dynamo room, which is steam driven at constant speed in a field of which the excitation can be varied from maximum to zero, reversed and increased to a negative maximum. The voltage of the generator accordingly varies as its field varies, and the motor armature receiving this varying voltage while its field remains constant, its speed will vary in a corresponding manner. The regulation of the generator field is effected from a controller under the sighting hood in the turret. The control is said to be extremely sensitive and precise. Retardation is effected with smoothness and rapidity by dropping the excitation of the generator to a point which gives a voltage below that corresponding to the speed at which the motor is at the instant moving; the latter immediately begins to generate current, and therefore quickly absorbs the kinetic energy of the turret. In the latest ships the current so generated is taken up on a braking resistance.

Most nations are now employing electricity to greater or less extent in turrets. Even Sweden is building cruisers in which the working of the turrets and guns is entirely electric. Among the best examples of electric turrets are those designed by M. Canet,[1] and built in France for many governments. The essential feature of M. Canet's design is that the turret is, as a whole, primarily designed for electric working. He arranges that the center of gravity of the moving mass should as nearly as possible lie in the axis of rotation. This insures moving with minimum power. In the Chilean *Capitan Prat*, for example, a 9-inch turret, weighing 87 tons complete, was rotated by a 15-H. P. motor at two-thirds power and could be turned by four men through 270 degrees in one hundred and seven seconds. It could be moved through one-fifteenth of a degree at a time.

If electric power is to render its best services in connection with ordnance work, it seems pretty clear that the turret must be designed throughout for electric working. To tack electric motors on to an unbalanced turret designed for hydraulic working is not the way to success. If the turret be fairly balanced, a great saving in power, weight, and complexity might be effected by employing electrical gears. Of course, a large margin of power and strength are needed to insure the successful operation of the turret when the ship takes a list in a rough sea or while turning, but allowing for this, it would seem that the aggregate power, if everything were electrical, might be of the order of 100 B. H. P. normal to 150 B. H. P. maximum under worst conditions. Allowing 250 B. H. P. maximum in motor capacity to provide for duplication where possible, the motors, with their gears, switches, and connections would certainly show a saving of 5 to 10 tons per turret on the aggregate weights of the hydraulic cylinders and gears, while the weight of the main hydraulic engines and transmission pipes (about 25 tons) would be a set-off against the weight of the electric generators.

ELECTRIC AMMUNITION HOISTS

for serving the 6-inch and smaller guns are in use in many navies. The *Powerful* and *Diadem* classes of cruisers were fitted with them, but the later English ships are fitted only with hand gears. In the United States and Japanese ships they are usually found. The apparatus consists of a quick-running motor of 2 to 5 H. P. geared in some way to a light whip or chain tackle for lifting small parcels of shot and shell at high speed. The motors must be so controlled that they start, stop, and reverse very quickly, with automatic brakes to hold them as soon as the current is switched off, or else the motions must be effected by clutch gears thrown in and out of connection with a continuously running motor. The latter arrangement is used by Messrs. Armstrong with friction gears. Fig. 36 shows the arrangement in plan. The motor shaft being in rotation, a vertical lever acting at O along the axis of the shaft puts either of the speed cones A or B into gear with C, thus driving

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[1] See detailed descriptions in *Engineering*, vols. 59 and 60, 1895.

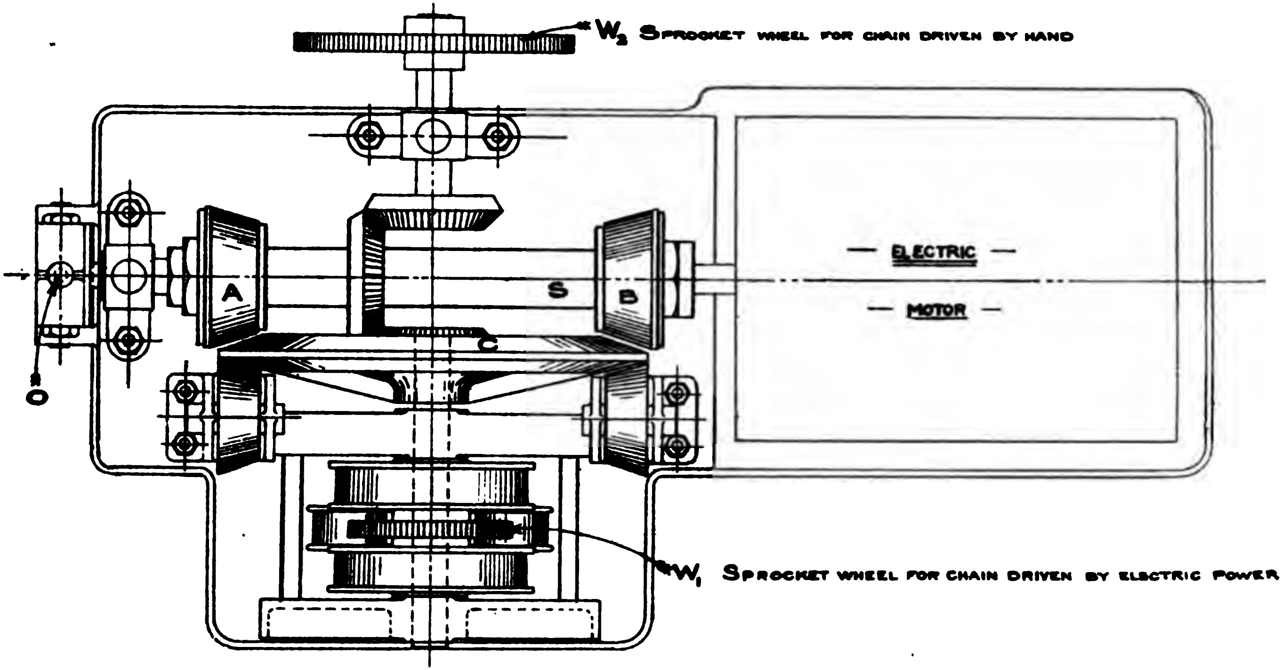
W₂ Sprocket wheel for chain driven by hand
ELECTRIC
MOTOR
A
S
B
C
O
W₁ Sprocket wheel for chain driven by electric power

FIG. 36.—Electric Ammunition Hoist Gear (Sir W. G. Armstrong, Whitworth & Co.).

THE NORRIS PETERS CO. PHOTO-LITHO., WASHINGTON D. C.

sprocket wheel W1, over which an endless chain runs, passing also over a fixed sheave at the top of the hoist. The cones A and B being out of gear, and therefore running free, the cartridges or projectiles in a bag are hooked on to the chain at the bottom, the friction gear brought into action, and the ammunition rapidly hoisted. Then, while this bag is being unhooked at the top, another round is being hooked on the other side of the chain at the bottom, the cone gears are reversed, and the second charge hoisted, and so on. There is an automatic arrangement for throwing the cones out of gear at the right time for each lift; there is an alternative hand gear working through the sprocket wheel W2 with arrangements for preventing both the hand and power gears being in operation at once, and other details not shown in the sketch.

Summing up the power requirements enumerated in the foregoing paragraphs we get—

	Total motor capacity installed, including duplicates.	Maximum demand for power, duplicates excluded.
	E. H. P.	*E. H. P.*
Ship ventilating fans	40	40
Engine and boiler room fans	100	100
Furnace air-blowing engines	200	200
Steering engines	400	200
Forward capstan	120	120
After capstan	50	50
Boat hoists	100	100
Coal hoists	100	100
Ash hoists	20	20
Workshop engine	5	5
Air compressors	200	100
Turret motors	500	300
Ammunition hoists for 6-inch and smaller guns	50	50
Total	1,885	1,385

If these figures err, they err on the large side. In working out details, savings, both in power and weight, could probably be effected.

There are no conceivable circumstances in which the whole of these machines could work simultaneously. The worst conceivable case supposes that in time of action all the gun-working machinery, air compressors, furnace engines, ash hoists, ventilating fans, and steering engine would be at work together.

Then the aggregate horsepower demanded would be, according to the above figures, 1,015 E. H. P. input to motors = 760 kilowatts. The lighting of the ship would involve 50 kilowatts, and the searchlights—if it be conceivable that all this mechanism could be employed at night when searchlights were wanted—a further 50 or 60 kilowatts. But, taking into account the fluctuating demands of current made by the motors, and the fact that it is hardly physically possible for everything to be working at the top of its load at precisely the same instant, about 600 kilowatts output would meet all requirements and cover distributing losses, while 800 to 850 kilowatts installed in the ship would leave an ample margin of spare plant in all ordinary circumstances.

Now this is an equipment not at all unlikely to be called for in the future. It will not come all at once, but it may come sooner than many would allow. What should be the arrangement of plant and system to successfully cope with it?

It seems clear that an installation of 800 kilowatts is not to be provided by the multiplication of 50-kilowatt sets. Yet it will always be desirable for battleships to carry a few sets of 50-kilowatt size—(*a*) for lighting and ventilation when nothing else is doing; (*b*) for working searchlights; (*c*) for regulation of turret and steering motors, should that method not be superseded by something better. But after 200 or 300 kilowatts are reached, it would be wise to introduce sets of 150 or 200 kilowatts capacity; the latter for preference. Then for an 800-kilowatt installation we might well have three sets of 200 kilowatts each and four sets of 50 kilowatts, there being enough sets of each size to form an efficient reserve. It would be most undesirable to introduce a lot of intermediate sizes.

In regard to the electrical system to be employed for distribution, two questions at once arise: (*a*) Whether continuous currents should be employed throughout, or whether polyphase currents should be introduced for the motors; (*b*) whether the existing standard of 80 volts should be retained.

(*a*) In view of the fact that machinery on board ship gets very little attention, it has been urged that polyphase motors should be used on shipboard, because they do away at once with all commutator troubles. But it is to be urged that well-built modern continuous-current motors give next to no trouble at the commutator, and that even the polyphase motors would require collecting rings and starting resistances. But the chief objections to the introduction of polyphase machines on board ship are the disadvantage of having two systems of distribution in the ship, and the introduction of the third cable. Possibly the relative advantages and disadvantages are pretty evenly balanced. At any rate, polyphase motors have actually been introduced by the Austrian navy on their coast defense ships *Budapest*, *Wien*, and *Monarch*, the currents being generated by composite machines which give continuous currents from a commutator on one end and three-phase currents from collecting rings at the other end of the armature.

(*b*) The question of the voltage standard is of greater difficulty; 800 kilowatts at 80 volts means 10,000 ampères to distribute, which represents a very formidable amount of cable work. If the pressure were doubled, the currents would be at once reduced to 5,000 ampères and the saving in weight and cost of cables would be material. The United States battleships *Kearsarge* and *Kentucky* are wired on the three-wire system, with 160 volts between the outers. The motors are in general arranged on the 160-volt mains, though a connection is usually taken from the middle wire to provide for changes of speed by switching the motor on the low-voltage mains. Searchlights and incandescent lamps are arranged on either side of the system to make an approximate balance, as is usual. The results of experience in these ships will be watched with great interest. The author is a little diffident as to the introduction of a three-wire system on board ship, and would rather prefer a direct circuit of 160 volts for both lamps and motors. Indeed, having got so far, one might as well accept the 200-volt standard at once. Searchlights in such an installation could be operated with very little complication through "series-parallel" switches, which, in the one position, would put two searchlights in series, and in the other position put each searchlight on separate circuit on the mains, with the addition of a resistance capable of absorbing the remaining volts. With automatic lamps this should be quite feasible, and any difficulty attending the use of so large a resistance as would regulate the arc down from 160 or 200 volts would probably be less than the difficulty of maintaining a balance of voltage on the two sides of the three-wire system when the searchlights worked intermittently, if that system were used. Of course the use of 200 or even 160 volts generally would impose a greater strain on the insulation of the cables and fittings than is now experienced, and would require some improvements in the design of fittings established; but there are no serious difficulties here.[1]

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[1] Between the dates of printing and of reading the paper, the Admiralty issued a circular to the effect that 100-volt dynamos would be used instead of 80 volts in future ships, beginning with some laid down in 1899.

Instead of the Tree system of wiring as at present adopted, all the main cables should be run in rings round the several decks back to the switchboard; through connecting boxes being provided at intervals of 100 feet or so for rapid disconnection and testing. With such an arrangement a circuit might be injured or shot away in any place without affecting the main supply of current. Separate ring mains for lights, searchlights, and motors should, of course, be used with throw-over switches to connect one to the other on special occasions. It would be desirable to divide the main switch board into two parts in the machinery room, connected together by switches which would form the closing links of the ring mains, the object being to avoid the possibility of a total breakdown by fire at the main switch board, which always exists when all the cable connections go through one narrow neck. Of course all the casings and other woodwork now used about switchboards should be rigorously abolished. The cable distribution should be expressly taken into account and allowed for in the design of the ship, proper trenches or culverts being provided for the cables. At present no such provision is made, and it is often a matter of considerable difficulty to find suitable runs, especially where cables have to pass watertight doors and the like.

Returning now to the generators, the question arises as to the possibility of providing the necessary weight and space; 800 kilowatts in generators of the existing type with double-acting engines, at speeds of about 400 revolutions per minute, would involve with steam and exhaust connections about 80 tons. This is the only increase in weight, as the motor weights balance out; the additional weights mentioned in the detailed descriptions of the motors above being counterbalanced by the saving which would be effected in the turrets if electrical machinery were substituted for hydraulic for gun working. The weight of the main hydraulic equipment, 25 tons, is a credit against the generator weights. There would indeed be a slight saving in the weight of distributing cables and switchboards as compared with the auxiliary steam and exhaust pipes now required for the services in question, but it would not be much. Approximately 55 tons of additional weight, then, has to be carried. In discussing the question of coal consumption it was shown on the figures there stated that the substitution of electricity for steam for all the auxiliary services would result in the saving of 262 tons of coal for every 25 days' steaming. This figure was calculated upon data assumed to represent the best possible conditions. Some of the engine and boiler room pumps have been assumed to remain steam driven, but if electric driving be applied to the services enumerated and if only one-half or one-third of that estimated saving were realized, there would still exist a strong prima facie case for the adoption of electrical power.

The weight of generators might be materially diminished by the employment of single-acting engines driving dynamos at higher speed, and still more by the adoption of turbine-driven sets; the weight of the units mentioned could be done with Parsons turbo-generators, including condensers for about 60 tons. Single-acting engines and turbines have both been used in the Navy; unfortunately both have failed, and, as a consequence, both are at present looked somewhat askance at for the purpose. They require dry steam; hence one of the principal sources of difficulty in the old arrangement, but one that should not occasion much trouble in the new. This consideration, coupled with the very great improvements that have been made in both since the days when they were used in the Navy, may bring them into service again.

The space required for the generators for the power mentioned would lie between 800 and 1,000 square feet, whichever of the three systems be adopted. It is not easy to find this room in an existing battleship; but on the hypothesis, the main hydraulic engines would not be wanted, and the space occupied by these two rooms would be available. If in consequence of savings on account of efficiency less coal were carried, though a saving of weight would be appreciated, little space would be added for the purpose of generators. Possibly the change to electric driving might be carried out in conjunction with some other change in the disposition of the *matériel* in the ship. For example; there are not wanting critics who consider that it is out of place in these days for ships of the fighting line to carry torpedoes. Should such a view obtain official support, a room equivalent to one of the existing submerged torpedo rooms would make an ideal generating station. Its locality would be, for preference, immediately adjoining the forward boiler-room bulkhead, so that the steam connections might be short and direct.

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WIRELESS TELEGRAPHY.

Many experiments are being carried out abroad in the use of wireless telegraphy. France has fitted some of the Mediterranean squadron with outfits and trials have been carried out between the different ships and between the ships and forts ashore. The results are reported as being very satisfactory. Russia has also obtained satisfactory results in her navy with the Popoff system. Wireless telegraphy has been used by the British in south Africa, where by the use of kites for the vertical wires, it was found possible to transmit messages over a distance of 85 miles. Some of the vessels of the Channel fleet have had apparatus installed on board, and it is the intention to give the system a severe test during the summer manœuvres. Germany has been experimenting with the Marconi system. On May 15 a maritime telegraph station was established, by way of experiment, on board the light-ship *Borkum Riff*, with limited day service from 6 a. m. to 8 p. m. The new station is connected with that of the Borkum lighthouse. The object being to transmit messages from and to ships at sea. The North German Lloyds Company are said to be equipping their ships for its use.

Wireless telegraphy is very ably described in the following lecture, by Mr. A. Slaby. Attention is also called to the article upon the same subject in the last annual of this office.

Extract from *Jahrbuch der Schiffbautechnischen Gesellschaft* (Yearbook of the Society of Naval Architects), Vol. I, Berlin, 1900.

THE EMPLOYMENT OF SPARK TELEGRAPHY IN THE NAVY.

While the practical value of Marconi's invention was much doubted in the beginning, it has now become well established, at least for certain purposes, and the navies of all seafaring powers are engaged in adopting and perfecting the new system of telegraphy as a valuable complement to the signaling devices already in existence. In designing new ships in the future provision will have to be made from the outset for the installment of the necessary apparatus and wiring where it will be free from disturbances as far as practicable. For this reason naval architects will probably be interested in spark telegraphy. I believe I can best discharge the duty assigned to me by explaining first the principles of the installations by experiments, then speaking of the progress recently made, and finally of the points of view which apply specially to naval purposes.

The new system of telegraphy, as its name indicates, utilizes exclusively the effects produced by an *electric spark*. The assumption is that an invisible, infinitely fine substance, which pervades all bodies as well as the atmosphere and the infinities of the universe, and which is called ether, is so violently agitated by the electric spark that the effects of the impulse radiate through space in all directions in wave-like motions. Heinrich Hertz has demonstrated by his famous experiments, made about ten years ago, that the electric radiation emanating from the spark follows all the laws of light and is propagated with the same velocity.

Wave-like effects, which in light and electric phenomena are as yet of merely hypothetical significance, are shown by nature in other instances. If we strike a tense cord, we notice that the blow is propagated in waves along the cord. Here we observe a wave in a linear medium. If we agitate the surface of a body of water by throwing a stone into it, we see surface waves in circular radiation carry the disturbance on and on. Here we notice, in addition, the velocity of the propagation. When we lie dreaming on the beach the melodious splashing of the wave against the bow of a steamer passing at a distance does not become perceptible to the ear until the steamer has long been out of sight. The surface wave facilitates the conception of a spherical wave in space, even though our senses can not perceive it.

We must imagine an electric spark as the point of departure for ether undulations in space. It is not the electric spark alone which possesses this faculty. Any change, any modification of intensity, of an electric phenomenon—e. g. a current—produces similar effects. This may be seen the most clearly in the alternating current. Each change in the direction of the current produces an ether wave. It is as though we were touching a water surface with one finger at one and the same spot many times in rapid succession. After a little while a cork floating anywhere in the vicinity will begin to dance up and down with the same rhythm. If we introduce a suitable body into a space filled with electric waves, the undulating motion will be communicated to the former; it will begin to rise and fall, keeping time to the motions of the electric waves. The effect—in this case the electric current—causes it to oscillate at the same rhythm. A few experiments will show this.

Through a coil of wire wound on an iron core I send an electric alternating current, generated at the distant engine room, and bring near it a second coil, the ends of which are connected with an incandescent light. We see a bright flame, though there is no connection by wire with the first coil nor with the current generator. I can materially increase the heat effect of the induced current. I hold a solid copper ring free in the air above another coil through which an alternating current is passing and which has a longer iron core. Before long it will be brought to a red heat. By suddenly closing the circuit of the alternating current I produce shock effects. An aluminum ring is thrown up to the ceiling. A hollow copper ball dances free in the air above the coil like a glass ball on a jet of water. If I shunt off part of the electric radiation so that the ball is struck on one side, it will begin to rotate rapidly.

But these remarkable phenomena of radiation, which Elihu Thomson was the first to demonstrate, are not adapted for long-distance work. Even at a short distance from the point of departure of the ether undulations the effect becomes exhausted. It will not be possible by oscillating the atmosphere to illuminate a whole city so that everyone could carry his own little lamp with him, though this would be the most ideal solution.

A closer study of the phenomena shows, however, that the effect extends the farther the faster we cause the waves to oscillate and the more violent we make the impulse, or, speaking metaphorically, the faster and higher we cause the mountains of waves to rise. Hence we must strive to produce short and intense waves. The intensity of the waves, in the language of the electrician, is called "electric tension." The latter can be increased at will by means of transformers. But the generation of rapid oscillation presents difficulties. The electric waves of which we have made use in the foregoing experiments must be designated as extremely slow from this point of view. We were able to produce only 100 alternations a second, and as many impulses were communicated to the ether. Even a hundredfold acceleration of the same would mean an insolvable problem for the constructors of dynamos. No material could resist the requisite number of revolutions of the armature. But noteworthy long distance effects can be expected only if we succeed in increasing the number of oscillations a millionfold. Fortunately, however, we need not invent such a machine; it is in existence already. Nature herself places it at our disposal in the electric spark.

What is the electric spark and how is it produced? If we increase the electric tension between two bodies beyond a certain degree, there occurs a sudden equalization—an electric current—in which particles of metal carried along are brought to a red heat. That is the electric spark. We must distinguish between two different kinds of sparks. One kind induces a permanent current, which may be either continuous or alternating. This device here will illustrate it. As soon as the electric tension between the two thick copper wires has attained a certain degree a spark springs across and establishes permanent connection. Thus is formed the so-called arc of light. Owing to the horn-like shape of the wires, the arc is drawn apart in the rising current of air until it breaks. The phenomenon then begins anew. In the flame of the arc of light pulsates an alternating current of the same low frequency as generated by our dynamo.

In the other kind of spark we first accumulate a certain quantity of electricity. The equalization is more violent in that case. It disturbs not only the ether, but, if it is strong enough, also the atmosphere, which is a billion times denser, and produces a violent detonation. We will charge the coating of this battery of Leyden jars until such an equalization is effected. We notice phenomena resembling lightning. The process is similar to that of the explosion of a steam boiler. Still more aptly we may compare it to the tense string of a crossbow. When we release it a violent shock is produced, because the accumulated energy is suddenly set free. But the string does not immediately return to the position of rest, nor does the electric phenomenon. Like a strong emotion in the human heart, so the electric excitation continues to vibrate in the spark in the shape of alternating currents with rapidly decreasing intensity. They oscillate with astounding velocity, about 10 to 100 million times a second, so that the human eye can hardly perceive the changes. We aid it by looking at the spark reflection in a rapidly rotating mirror. The successive spark currents are thereby drawn apart in the reflection, and we recognize in the one spark a whole bundle of sparks. Each discharge of sparks produces a new bundle of spark currents, in which the electric phenomenon undulates back and forth.

Another experiment will show that we have actually to do with electric currents and that they are alternating currents. We connect with the poles of a spark gap wires stretched rectilinearly, secured to and insulated from the opposite walls of this hall. The poles themselves we charge with alternating currents generated by our dynamo—that is to say, with 100 alternations a second—and place in the circuit a transformer for the purpose of increasing the tension. Incandescent lamps have been placed in the circuit of the wires. As long as the spheres are far enough apart so that no spark can be produced we observe nothing special in these wires. The transformed alternating current oscillates with its 100 alternations in the secondary coil of the transformer. We will now bring the spheres near enough to each other to produce a spark. The incandescent lamps are at once lighted and prove the presence of an electric current in the rectilinear wires. This can only be an alternating current, since we have no closed circuit such as would be necessary to excite a continuous current. Thus each impulse of current is sent from the spheres to the terminals of the wires and thence repelled back.

Such an alternating current of high frequency carries its effect for miles through space. Each spark produced by a wave of our slowly alternating current excites a whole agglomeration of waves which vibrate on—rush on, I should prefer to say if the ethereal motion were not noiseless. But the first mountain of waves in this surging is always the most powerful; it will rise the faster and its impulse will be the more violent the faster the oscillations. As the effect is conditioned upon the working efficiency per second, we attain here, with the enormous velocity with which the wave rises, a handsome number of horsepower, effective, however, only for the one hundred millionth fraction of a second. The time which elapses until a new discharge causes another surging of waves bears about the same relation to the duration of a wave impulse as thirty hours to one second. The interruptions are not perceptible to the eye; we see apparently one continuous current of sparks.

This will explain why the pulsations of the spark carry so much farther. With the slowly pulsating waves of our alternating-current dynamos we can never attain such effects. Their effects may be said to bear the same relation to the impulse of spark pulsations as a gentle tap on the cheek to the blow of a cannon ball against an armor plate.

In suitably shaped conducting bodies, which the ethereal waves may encounter on their way, they excite again electric alternating currents, the same as a wave in the water causes a floating cork to rise and fall. But this faculty decreases the farther the ethereal waves remove from their point of departure. It decreases with the square of the distance, exactly like the intensity of light radiating from an illuminating point, for a source of light is nothing further than a disturbed point in the ether, from which radiates an undulating motion, with a million times more rapid oscillation, however. Hence the power which the ethereal waves exert at long distances can be but infinitesimal. But as the most infinitesimal bacilli, when making their attack by the hundreds of millions, are able to destroy the most robust organism, so, also, countless minute ethereal impulses may also unite in a total effect of considerable power. For that purpose, it is true, the ethereal waves must first be made to travel in a certain direction. If we connect with the spark gap a rectilinear conductor, the wave impulses will emanate especially from the latter, and are thus polarized; that is to say, the particles of ether oscillate in one direction only, namely, the one which is parallel to the conductor. In that case their effect no longer decreases with the square of the distance, but simply with the distance. If on their march in this rigid formation they encounter another linear conductor, they are drawn to it from every direction, like a swarm of flies to a lime twig. A concentrated general attack takes place, which causes along the wire a stormy rising and falling of electric forces, or, in other words, a pulsating, alternating current of high frequency. An astounding increase of effect may be attained by means of such transmitting and receiving wires. Thorough experiments have convinced me that the effect depends on the length of the two wires and increases almost exactly with the product of the same. For instance, with wires of 6 meters length on both sides we obtain the same effects as with wires of 4 and 9 meters, respectively. The product is the same in both cases. With equal length of wires in the transmitter and receiver the effects vary, therefore, with the square of each length of wire, and since, as previously mentioned, the effects decrease simply with the distance, it follows that the distances to which equal effects may be transmitted vary with the square of each length of wire. An example will show the great importance of this statement. If with 10-meter wires on both sides a certain effect is obtained at a distance of 5 kilometers, the same effect may be observed with 20-meter wire to a distance of 5 times 4, or 20 kilometers; with 30-meter wire to a distance of 9 times 5, or 45 kilometers—a marvelous law for long-distance effects, which admits of almost unlimited extension.

In order to detect the alternating current in the receiving wire different means are at our disposal, but we can make use only of the most sensitive ones. The telephone, for instance, is suitable. In the front part of this hall we will produce a spark gap and polarize the oscillations by the insulated horizontal wires connected with the poles. The ethereal oscillations throughout this whole hall will then take place in a horizontal direction. As receiver we use two wires in the back part of the hall, likewise stretched horizontally, and with their central terminals connected with the telephone. As soon as I excite sparks here in front you will hear a sound in the telephone. It corresponds to the number of oscillations of our primary alternating current (100 per second), for the oscillations of the current of sparks itself take place in too rapid succession for the ear to perceive them, since the limit of audible sound, as is well known, is at 40,000 oscillations a second, and in the electric spark we have 10 million oscillations a second. By making the sparks short or long I can telegraph the characters of the Morse alphabet without a connecting wire.

The distance attainable in this manner may reach several kilometers, provided the transmitting and receiving wires are of corresponding length. It is even possible to transmit through space from one wire to another the complex slow oscillations of the human tongue. We may make this experiment ourselves every day, sometimes to our annoyance, when at the telephone we are perhaps listening to some important family news and have to take in at the same time an order for the sale of some goods for Mr. So-and-so. That is wireless telephony; it does not have to be invented. It is true, though, that it extends only from one wire to another on the same pole.

In order to utilize directly the rapid waves of the current of sparks for signaling purposes we will make use of a device which may be considered the reverse, so to speak, of the wave generator, for here we generate sparks from intercepted ethereal waves from the alternating currents induced in the receiving wires. This can best be shown by an experiment. I have here two pieces of porous carbon, which are only a short distance apart. The velvety surface of the carbon is formed of a lot of microscopic points. If I connect the pieces of carbon with the receiving wires, through which current pulsations are passing, the electric waves spray, so to speak, between the little points as though passing over an obstacle, and we perceive sparking. It is an arc lamp in miniature, fed by ethereal waves. I can prove that the sparking is actually caused by the rapid pulsations, for if I produce an alternating current arc of light with a low number of oscillations, as before, the continuous sparking at the receiver will cease. We perceive a spark only when the arc of light is forming, and thus we detect the ethereal impulse. When the arc of light has been fully formed, no more spark pulsations occur—only slow oscillations of the alternating current. Our receiver does not respond to these; it requires an impulse.

These tiny sparks can be utilized to free greater forces. I could easily cause the detonation of an explosive substance. I will, instead, make an experiment causing less noise. Back there in the hall is an arc lamp. The carbon points are connected with the poles of an accumulator battery, but do not touch each other, so that no current can pass across from one to the other. With the carbon points are also connected the long electric-wave receiving arms. The sparking caused by these waves forms a conductive bridge between the carbon points and closes the circuit of the accumulator battery. A single spark at the radiating apparatus here in front is sufficient to cause the arc lamp back there to glow.

A device like this would be sufficient for telegraphing, except that provision would have to be made for breaking the current of the accumulator battery after each lighting of the arc lamp. But I can render the interrupting of the current automatic if I replace the arc lamp by an ordinary incandescent lamp. The slight current passing through the latter breaks of itself as soon as the sparking at the carbon points ceases. You will notice that I can even make perceptible the characters of the Morse alphabet by the longer or shorter duration of the glowing of the incandescent light.

To cause the explosion of the ammunition room of a hostile ship by such long-distance effects does not, therefore, appear an insolvable problem. Only the enemy would have to be kind enough to place pieces of carbon among their powder supplies and connect them with long receiving arms in the open air. However, for the formation of sparking on board ship this jest assumes a more serious meaning. It is by no means impossible for electric-light wires to play the part of receiving wires in some undesirable manner. If at some spot they should be too near each other and at the same time imperfectly insulated, even the most insignificant sparking may cause a perfect short-circuiting of the wires. If the installation is otherwise perfect, no harm will be done except the burning out of the safety fuses. This was what happened on board H. M. S. *Friedrich Carl.* In any event, this circumstance must be taken into consideration in installations for spark telegraphy on board ship, and a careful examination of the wiring from this point of view is necessary. The armatures of dynamos on board may also be broken by such sparking; they must therefore be fitted with lightning protectors. The ammunition rooms are sufficiently protected by being entirely lined with metal, and, as far as I am aware, electric-light wires are not allowed to be passed through them.

The devices used by Marconi for signaling are very similar to those just described. The carbon points are replaced by metal filings thrown loosely together. These are inclosed between two silver pole pieces in a small glass tube and may be connected, by means of two platinum wires fused into the tube, with the electric-wave receiving arms. Each particle of the metal powder is covered with a thin coating of oxide, such as most metals take on in the open air, and thereby insulated from its neighbors. Even if, in addition to the connection with the receiving wires, we connect the extremities of the tube with the wire circuit, into which are introduced a local cell and an ordinary telegraph relay, no current will be formed, because the circuit is broken by the metallic powder in the tube. But if the rectilinear wires receive polarized electric waves, the infinitesimal sparks, invisible to the eye, establish a connection between the particles of metal. Thus is formed, perhaps with the assistance of condensed metal vapors, a bridge for the continuous current of the local cell, and the latter actuates the relay. A stronger local battery is thereby closed in the usual manner, actuating an electric bell or a Morse recording instrument. Slight tapping on the tube breaks the loose connections between the particles of the metal powder and restores original conditions. Here, also, the characters of the Morse alphabet may be transmitted by shorter or longer radiation. In that case the relay tapper is actuated by the current of the local battery. The process which takes place in the tube is similar to the process technically known as "fritting;" it is therefore called "Fritter" or "Frittröhre" (fritting tube). The English call it "coherer," and the French "radio-conducteur."

The coherer is an extremely sensitive and very accurately working means for establishing the presence of electric-wave impulses. By experiments we can prove, for instance, that electric radiation follows the same laws as the radiation of light.

The laws of electric radiation have been known for ten years, thanks to Hertz's experiments. The faculties of the coherer were discovered by Branly at Paris in 1891. In 1895 Popoff, at St. Petersburg, made the first practical application of the new phenomena for recording lightning discharges during thunderstorms. He used a receiving apparatus which in principle is entirely identical with that since used by Marconi. Marconi's principal merit consists in the careful adaptation of the apparatus for practical telegraphy, and during his experiments he arrived at the important discovery of the almost unlimited long-distance effects of vertically polarized electric waves. It is this discovery that has made spark telegraphy possible. For that reason Marconi's merits surpass those of his predecessors, with the exception of Hertz.

It is now three years since Marconi's discovery became known. What has been done with it since? The progress made bears, on the one hand, on a better understanding of the phenomenon and its laws and, on the other hand, and partly as a result thereof, on the increased technical effect. The latter, as far as Marconi himself is concerned, may be expressed in figures. In the spring of 1897 he telegraphed across the Bristol Channel, which is 5 kilometers wide, and used for that purpose transmitting and receiving wires of 50 meters length. The distance per meter of wire was consequently 100 meters. In the summer of the present year (1899), during the English naval manœuvres, Marconi, according to newspaper reports, sent telegrams to a distance of 108 kilometers with 45-meter wire. That means a 24 times greater effect.

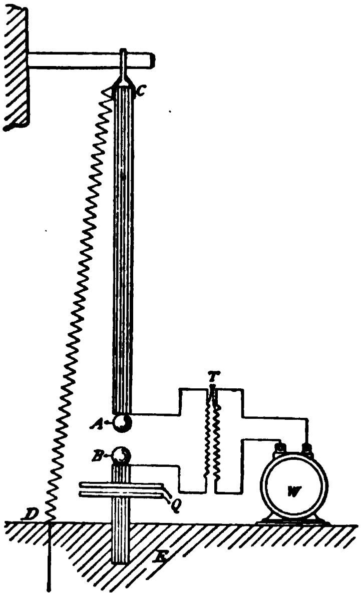
In the meantime experiments have been made in almost every civilized country. Particulars as to these, however, have not generally become known. Marconi himself maintains profound silence as to his improvements. What I am able to communicate, therefore, is only the result of experiments which I was able to make myself. They were rendered possible through the kindness of His Majesty the Emperor. Two summers in succession I was allowed to experiment on the *Havel* and to call on the personnel of the Royal Sailors' Station for assistance. The aëronautic division, also, at the suggestion of His Majesty, has made some very interesting experiments, which for a time gave Germany the world record, with a distance of 21 kilometers. His excellency the secretary of state of the imperial marine office had the kindness, during the summer and fall of the present year, to permit me to carry on experiments with some improvements on board the German war ships in the Baltic Sea. If I speak of these improvements to-day, I do not wish to create the impression that they are ahead of Marconi's. I am not acquainted with the means with which Marconi is working at the present time; I only know that they must be very much more perfect than those with which I became familiar through him two years ago. A direct comparison would be possible only if the experiments were conducted under identical conditions.

I will first take the liberty of setting forth briefly a theoretic conclusion at which I have arrived through these experiments, and which has not been without profit as far as the technical significance of the process is concerned. This theory, which really embodies a disappointment, is the explanation of the phenomenon by the effects of electric impulses, to which I referred at the beginning of my lecture. There was hope at first that by more clearly establishing the undulating character of the electric disturbance it would become possible to tune the receiving apparatus to definite lengths of waves. I am sorry to say that I have come to the conclusion that such endeavors are hopeless. The coherer is not to be compared to a pendulum which is gradually set to oscillating more rapidly by numerous impulses of low intensity succeeding each other at definite intervals. It is rather in a sort of unstable equilibrium, which is immediately upset by an electric impulse.

But from the above follows the important conclusion that we must seek to attain above all—a high energy of the impulses of the spark generator per second. But such energy does not depend only on the tension, but also on the quantity of electricity which we set free during the spark formation. It is exactly the same as in the falling of a body. If we release a suspended weight by cutting the cord, the effect of concussion as the weight strikes will be the greater the larger the bulk of the body set in motion, in addition to the height from which it falls. It is not the length of the spark alone that corresponds to the electric tension employed; there must also pulsate in the spark as large a quantity of electricity as possible. Let us examine the spark generators from this point of view. They are the usual inductors, the construction of which is controlled only by the production of as high tensions as possible. Inductors, as is well known, are classified according to the length of the spark. We speak of a 20 or 30 centimeter inductor. The quantity of electricity which is thereby set in motion is very small. It can be increased to a certain extent by decreasing the length of the spark. That is what Marconi does when he makes a 30-centimeter inductor work with a spark of 1 to 2 centimeters length.

A little computation will show the working power consumed. As a rule we work with a primary current of from 5 to 7 ampères and an 8-cell accumulator having a tension of 16 volts. This results in an electric working power of about 100 watts per second. As inductors have a very low efficiency, we will hardly be able to utilize with constant sparking more than 50 watts, or about one-fifteenth horsepower, for the generation of electric waves. For the first spark impulse the energy per second will naturally be considerably greater. Nevertheless the primary work consumed may furnish a standard for the purpose of comparison. For obtaining increased sparking effects we shall therefore have to discard the inductors and use dynamos instead.

There is no difficulty in producing electric energy of high tension with any desired quantity of electricity by means of alternating-current dynamos and transformers.



But the use of dynamos for the generation of sparks makes it necessary to discard entirely Marconi's system of circuiting.

The sketch shows a device which is at present functioning on board of German war ships. The alternating-current dynamo W, actuated by an electromotor, feeds the primary winding of the high-tension transformer T, whose secondary windings are connected with poles A and B.

The circuit of oscillations proceeding from these poles is one closed by the earth, but consists of two parts which differ from each other in their functions and effects. The difference is conditioned upon so-called self-induction. Electricians designate under this name a kind of inertia, possessed by all alternating currents, which is produced in a conductor. The conductor itself offers to an alternating current an extra resistance in addition to the ordinary resistance. The amount of this extra resistance is dependent on the number of alternations of the current; for currents of high frequency it may become so enormous that the generation of such currents is rendered almost impossible. But by the shape and disposition of the wires an influence may be exerted on the amount of self-induction. Thus metallic bands, or tubes, or wire cages, such as used in this hall, have considerably less self-induction than thin wires. The vertical conductors AC and BE have the smallest possible self-induction, while the connection CD between the summit and the earth possesses rather high self-induction. There is also put in the circuit a condenser Q, which is adapted to receive large quantities of electricity. The working of the device is as follows: The alternating-current dynamo, by means of the transformer, charges the spark gap AB to such a high tension that an oscillating discharge occurs. During the charging period—that is to say, before the appearance of sparks—the secondary coil of the transformer is closed through the entire circuit of oscillations, including the earth and the condenser. The portion of the circuit connected with A lies to earth through the wire CD, and therefore retains nearly throughout its whole extent the potential of the earth. The charging is effected almost exclusively in the condenser. While self-induction is of some influence on this process, such influence is not great, owing to the small number of alternations of the alternating current. But an immediate change is effected as soon as the sparking of the discharge current with its enormous frequency sets in. As to this current the high self-induction in the wire CD acts as a cut-off, and thus the rapid oscillations which disturb the ether are produced almost exclusively in the vertical conductor with low self-induction. But the enormous quantities of electricity previously stored up in the condenser have a share in this. It is obvious that we are thus able to convert into radiation far greater amounts of energy than with a Ruhmkorff inductor.

A similar system of circuiting is also to be recommended for the receiver, though for different reasons. In Marconi's system the coherer is connected on the one hand with an insulated vertical wire and on the other with the earth. Arranged in parallel with the coherer is the relay with its local cell. It is obvious that, while all electric impulses intercepted by the vertical wire have on the one hand the faculty of influencing the coherer and make it a conductor during sparking, such impulses, on the other hand, may also pass through the relay circuit directly to earth without passing through the coherer. The impulse will thus be divided, and not exert the full strength of its effect in the coherer. Marconi has sought to obviate this drawback by placing in the relay circuit coils of great self-induction. That is a good way, for the self-induction closes the path to the rapid oscillations, but it is not a harmless way, because the high resistance of the self-induction coils reduces the sensibility of the relay. If the upper terminal of the vertical conductor of low self-induction were connected with the earth, and the relay and its battery put in the circuit of such earth connection, the rapid oscillations intercepted by the vertical conductor would pass almost without diminution through the coherer to earth.

Another innovation relates to the construction of the receiving apparatus. In the Popoff system of circuiting, which is also used by Marconi, the relay circuit is broken by the tapping of the trembler on the coherer, hence in the coherer itself. Now, it is well known that the opening spark of a circuit is of much more injurious effect on the contact places than the closing spark. It is the latter that we use for signaling, and we have to put up with the wearing away of the fine points and edges of the metal filings. But it is different with the opening spark, which is detrimental without offering any advantages as an offset. An arrangement can be made so that by means of a special spring contact the breaking of the relay circuit is effected outside of the coherer and before the tapping of the trembler. By such a disposition the sensibility of the coherer is not only preserved for a greater length of time, but it insures also the more prompt making and breaking of the circuit.

These three innovations were the result of experiments which I made at Potsdam three years ago, in conjunction with my then assistant, Count Arco.

I now come to the employment of spark telegraphy in the navy. It is on the open sea that it functions under the most favorable conditions. It may be said that with the same installations from five to ten times longer distances can be overcome on the sea than on land. What is the reason therefor? I used to think that this was due to the fact that the atmosphere is purer and free from dust. But that is not the case, for telegraphing in the vicinity of the coast, where the air is probably as pure as on the open sea, reduces the distances. Perhaps the fact may be ascribed to a peculiar plane effect of the sea. It is true that the electric disturbances emanating from a spark are propagated in all directions through space, but they follow preferably conductors and semiconductors when these are in the line of propagation. The conditions are equally favorable in a plane. If the transmitter and receiver of a spark-telegraph instrument are brought close to the smooth and unobstructed wall of a large hall, the distances that can be reached are almost twice as long as when the apparatus stands in the middle of the hall. In order to carry out measurements, I had a large hall of my laboratory entirely cleared out, and could verify this circumstance along the wall of the same. We are inclined to believe in special plane currents. If we compare the surface of the sea, even when agitated, with the surface of the land, we notice at once a great difference. In the former case it is the smooth surfaces of the waves on which the electric impulses glide along; in the latter case the distances to be traversed are very much longer, for we must realize that the electric waves have to glide up and down each stone, even each grain of sand and blade of grass they encounter.

Another remarkable circumstance is to be noted here. When we use vertical transmitting and receiving wires the electric waves are polarized vertically. If they encounter in their path another vertical linear conductor of corresponding extent they remain clinging to it, so to speak, and generate in it a pulsating alternating current. I can easily convince you of this by an experiment.

It will now be understood why any linear elevations, such as trees, masts, flag poles, chimneys, and steeples, interfere so much with spark telegraphy. Telegraphing across a large city, unless balloons can be used for carrying long wires, is fraught with enormous difficulties.

But dampness also plays a part. On the sea neither fog nor rain are of disturbing influence. On land it is different. Trees, masts, and buildings are semiconductors under ordinary circumstances. When in a damp state, and still more when soaked through, their conductive power increases. They suck in the electric waves greedily and invite them to remain. My laboratory here is connected with my residence at Charlottenburg by a spark telegraph. Though the distance is not long, yet the electric waves have to pass through numerous obstacles. In damp weather I have to increase the spark power considerably in order to obtain distinct messages. On the sea such obstacles do not have to be reckoned with. Even in a crowded harbor the masts of ships are still far enough apart not to interfere seriously with electric radiation.

But it is different with the masts, shrouds, and cables of the ships directly concerned. These do constitute serious obstacles. Each ship must be considered a distinct individual from this point of view. Devices which on board of one ship had proved excellent, show less favorable results on board of others; but it is not possible to find at once sufficient reasons for this circumstance. Experience must here come to our aid; but experience can only be gained from continuous use.

The installations at present set up on board German war ships can, of course, not be publicly discussed, and I am not at liberty to express any opinion as to service regulations concerning spark telegraphy and the tactical employment of the same; but I may perhaps be permitted to state what has struck me as particularly important and favorable in connection with spark telegraphy, and that is the assurance and precision with which the installations were served by the crews of our very efficient engine personnel. I want to lay special stress on this, because we frequently hear doubt expressed on this point. There is an impression prevalent that it is a question of difficult physical apparatus which scientists alone can understand and handle. That is not the case. The chief mates who took part in the experiments had a good knowledge of the scientific working of the instruments and would often ask questions of my assistant and myself which left nothing to be desired in the way of thoroughness and intelligence; unfortunately we could not always answer them as intelligently. During the experiments, which extended over several months, minor disturbances and alterations in the apparatus were inevitable; these could nearly always be removed by the engine personnel on board. The most sensitive and at the same time the most important part of the apparatus is the coherer. Its construction is frequently surrounded with a certain mystery. However, the longest distance to which messages were sent on board H. M. S. *Friedrich Carl*, 48 kilometers with 30-meter wire, was attained with a coherer which the chief mate had manufactured himself on board with very little instruction. The man was a locksmith by trade. Hence, in this respect the installations for spark telegraphy are not to be compared with a chronometer, for instance, which could hardly be repaired so easily on board.

VI.

GRAPHIC TABLES.

By Lieutenant WILLIAM L. HOWARD, United States Navy,
Staff Intelligence Officer.

The following tables are intended to give some graphic comparisons of the principal naval powers. The data upon which they are based was taken from a British Parliamentary paper entitled, "Return showing the fleets of Great Britain, France, Germany, Italy, United States of America, and Japan, distinguishing: Battleships, built and building; cruisers, built and building; coast-defense vessels, built and building; torpedo vessels, torpedo-boat destroyers, and torpedo boats, built and building." This was compiled from the official list of each navy, and has been supplemented by some later data.

In making such comparisons it must be borne in mind that there are in every navy certain classes of vessels which appear in the official navy list, but which can not be considered as forming part of that navy's fighting force. These are:

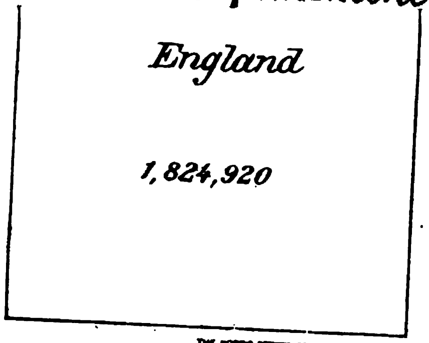
1. Obsolete ships.
2. Receiving ships.
3. Sailing and training ships.
4. Tugs, etc.

All these classes are omitted in the comparisons. Neither are there included any auxiliary vessels, such as yachts, merchant steamers, etc., for that would mean practically the addition of the merchant marine of the several countries, all of which is available.

It must also be borne in mind that, even after eliminating the above classes, there yet remain a certain percentage of vessels whose armor and armament have become obsolete, and whose principal duty is to swell the numbers borne on the official list, giving to such lists a misleading value. For this reason the comparisons shown by Table II of the tonnage built since 1890 give a better idea of the comparative fighting strength of the various powers, and here may be noted the enormous stride Germany will make by virtue of her new building program just authorized. This program practically doubles the strength of her fleet, so that if the ships authorized were included her position would be next to that of England and ahead of France.

TABLE I.

Total Displacements, Tons.



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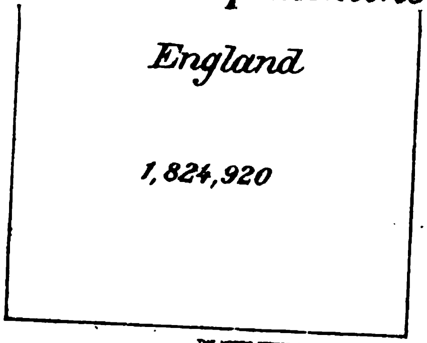

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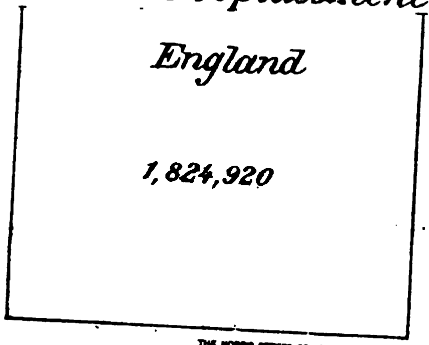

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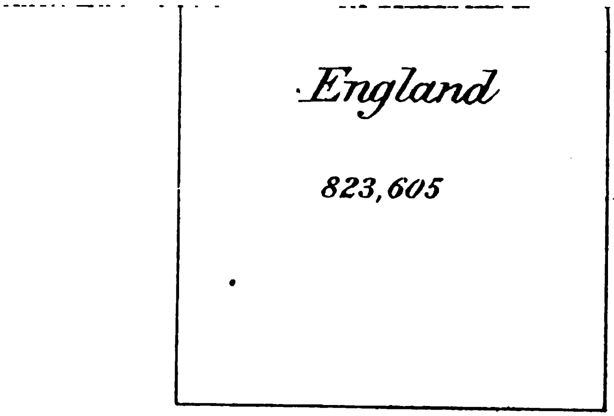
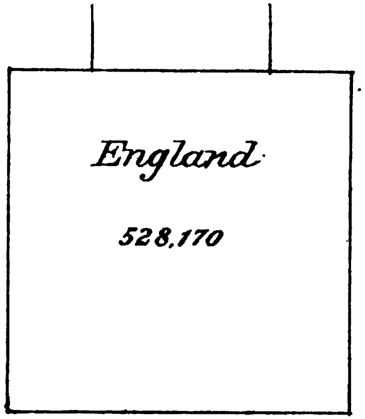


Battleships.



Protected Cruisers

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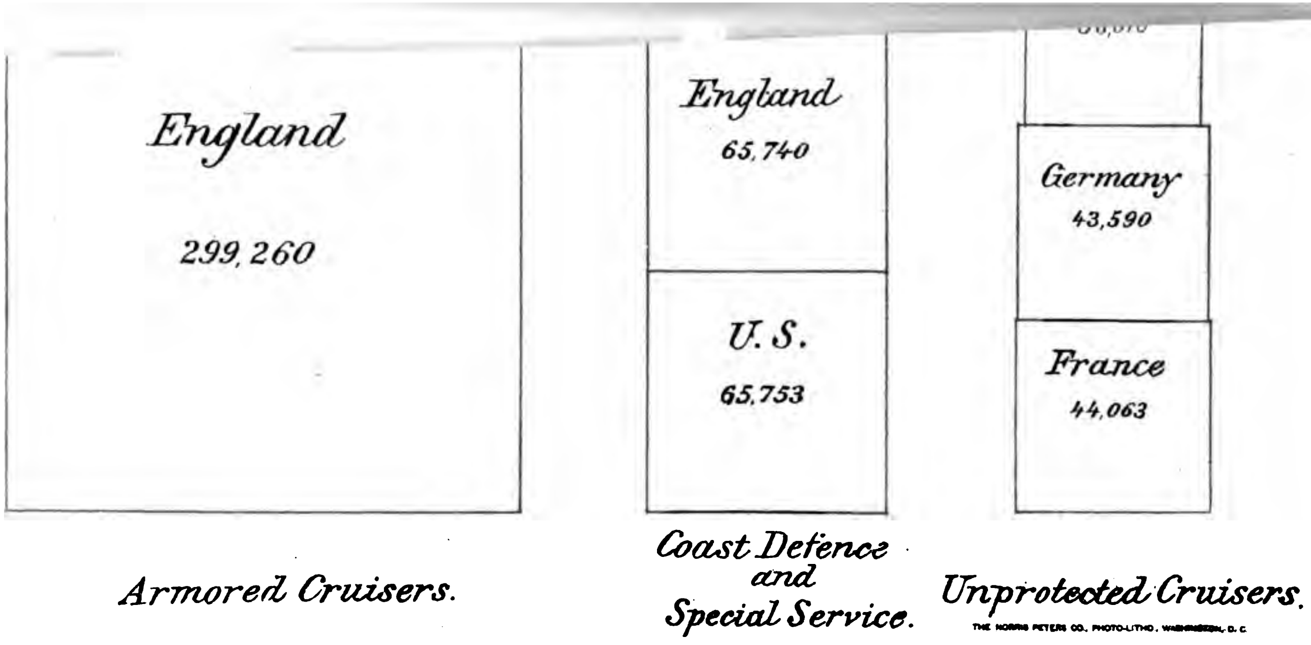

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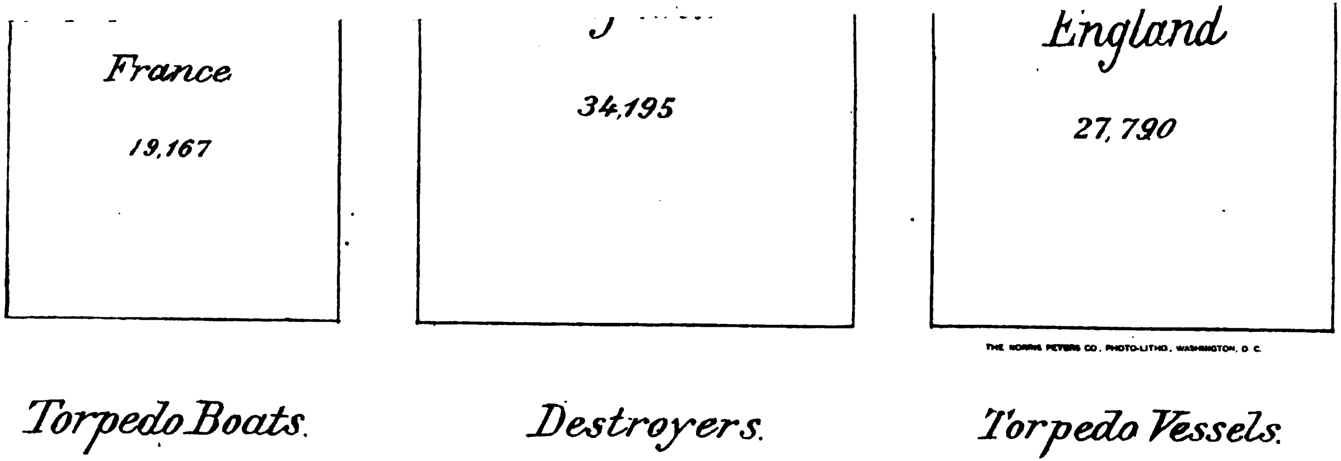
England



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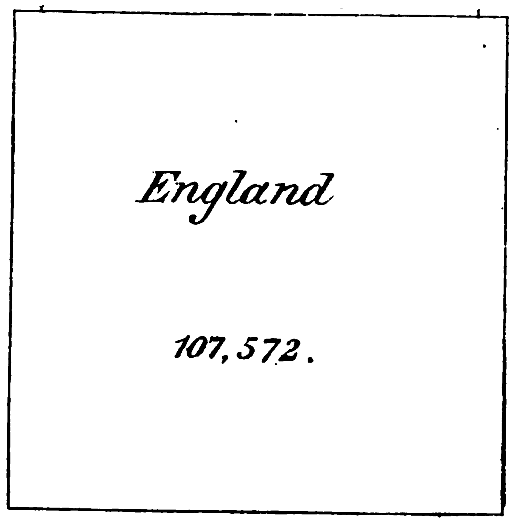
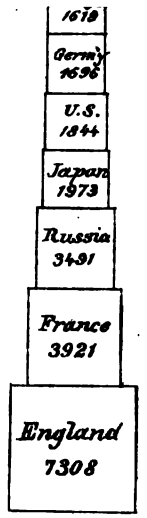


Petty Officers and Men.
(including Marines.)



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